HOW LONG WILL YOUR GLUE LINE LAST?—p. 187

# Forest Products Journal

Vol. VII, No. 6 June 1957

**John E. Wells, Laurel, Miss., Presents Furniture Valued at $3,000 for Proposed New FPRS National Office Building**

—See page 11-A

Photos by Roger B. Russell

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN

CYANAMID

# RESIN ROSTER

## You can handle almost any wood-bonding application with one of Cyanamid's versatile thermosetting resin adhesives

URAC® 180 — General-purpose, urea-formaldehyde resin in water solution. High-solids solution (66% PMMA Method) for drum, tank-car or truck shipment. Catalysts and hardeners available for all wood-bonding applications — cold- or hot-press plywood gluing, high-frequency gluing, fortification of starch-dextrine adhesives, etc.

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MELURAC 259 — Newly developed, one-package melamine-urea-formaldehyde resin for tapeless splicing of veneers, requiring addition only of water.

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MELURAC 301 — Powdered melamine-urea-formaldehyde resin without filler.

MELURAC 304 — A melamine-urea-formaldehyde resin developed expressly for use as a particle board binder. A fine, free-flowing powder that is easily handled. Imparts no color to the particle board. May be blended dry, or sprayed from water dispersion into wood chips or sawdust.

CYMEL® 401 — Hot-press melamine-formaldehyde plywood adhesive for use with or without fillers. May be added to urea resins to improve durability of bond and materially lengthen working life of glue mix. Also used for laminating heavy timbers in marine applications and for general-purpose work where a boil-resistant, non-staining bonding agent is required.

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# FOREST PRODUCTS JOURNAL

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**August:** Upper Mississippi Valley Section Meeting, International Falls, Minn.

**Fall 1957:** Carolinas – Chesapeake Section Annual Meeting, Roanoke, Va.

**Sept. 1957:** Inland Empire Section Meeting, Omak, Wash.

**Oct. 21–22:** Mid-South Section Meeting, Crossett, Ark.

**Oct. 31–Nov. 1:** Northeast Section Meeting, New York City

**June 22–26, 1958:** Twelfth National Meeting, Madison, Wis.

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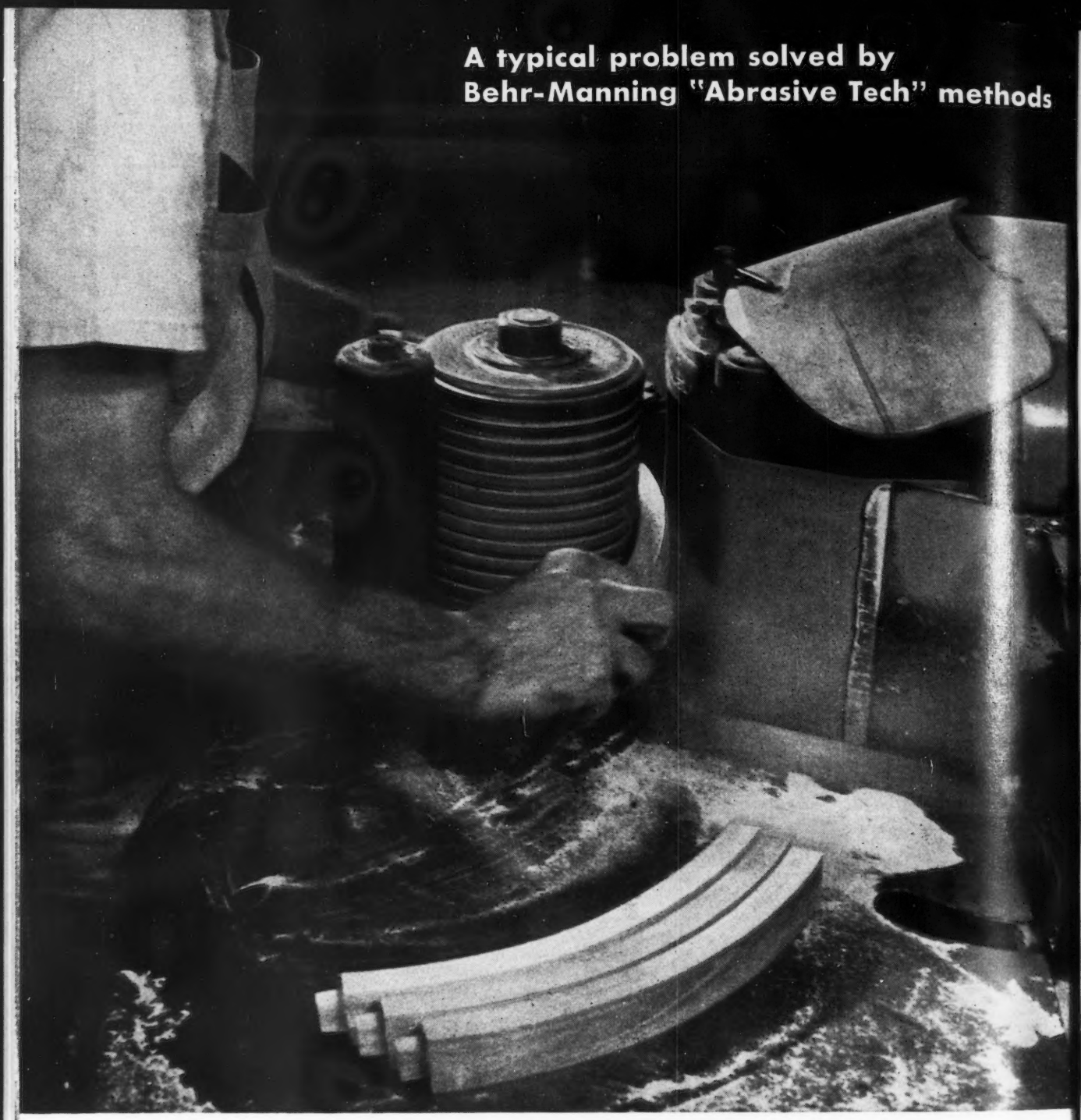


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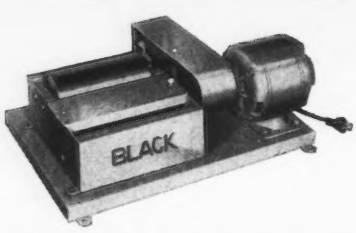

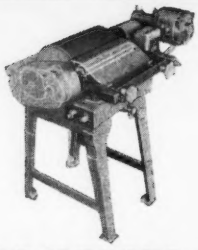
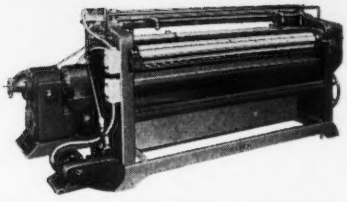

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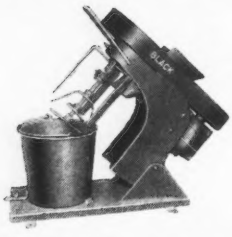
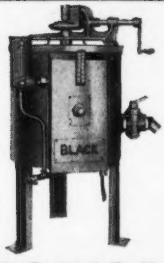
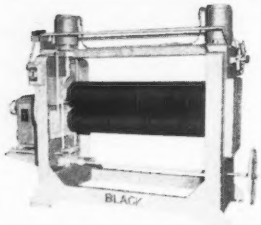
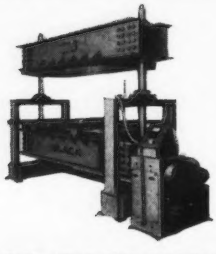
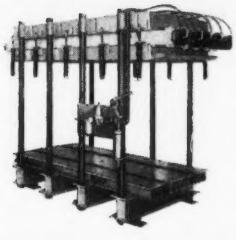
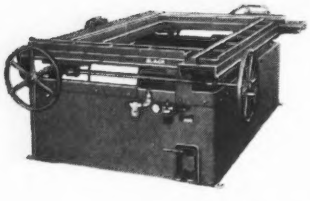
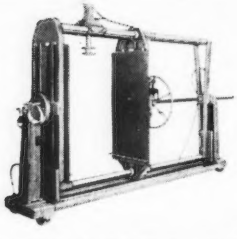
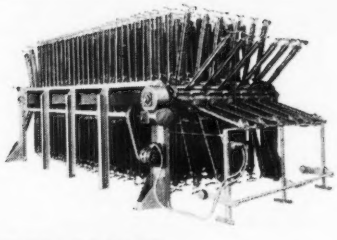





**GLUE MIXERS AND HEATERS FOR EVERY REQUIREMENT**

**COLD PRESSES FOR MODERATE PRESSURE LAMINATING OPERATIONS**

**PRODUCTION CLAMPS FOR EVERY NEED**

Illustrated above are but a few of the many items contained in Black Brothers Catalog No. 11. This new, complete catalog gives you illustrations, descriptions, specifications and numerous installation views of the Black line of Laminating and Gluing Equipment. Over 70 years of engineering progress is behind Black Brothers internationally recognized superiority in gluing and laminating equipment. Write for your FREE catalog now.

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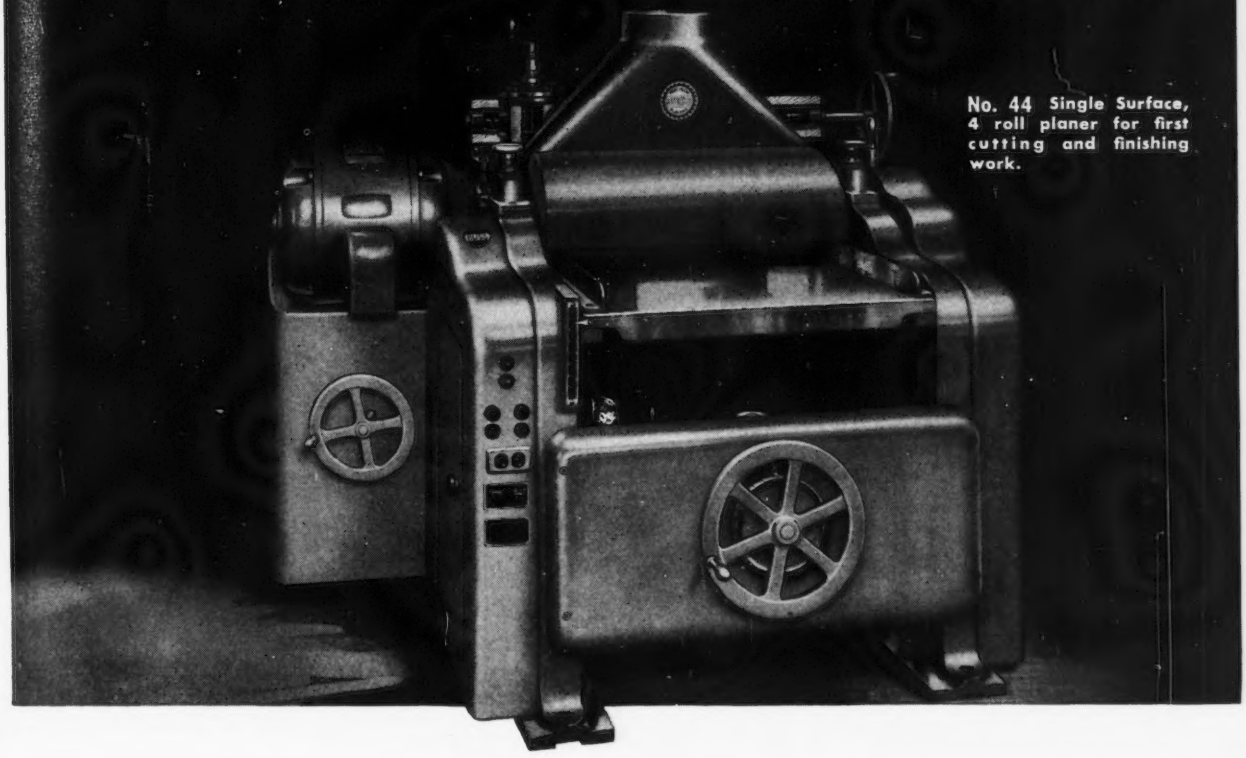
## ARE UNMATCHED FOR PRECISION PLANING



No. 44 Single Surface, 4 roll planer for first cutting and finishing work.

It takes a good mechanic exercising real skill and taking plenty of time for adjustments to produce first class finished planing on the conventional machine. On the other hand, an average operator will ***consistently*** produce ideal finished planing on a modern BUSS CABINET SURFACER and maintain tolerances as close as .002 an inch with only about one-third the non-productive time for set-ups and adjustments required on other planers. This is due to the fact that in addition to being built throughout for precision planing, BUSS CABINET SURFACERS are equippd with semi-automatic controls (not available on other machines) which make it easy for the operator to get perfect and almost instant settings. For the greatest production of the kind of planing that saves time on following operations, investigate BUSS CABINET SURFACERS. Write for bulletins. Consult us on any planing problem.

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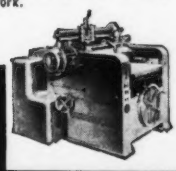
6 MODELS
29 SIZES

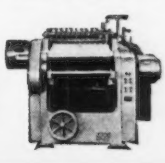
No. 4-L Single Surface, medium sized planer for first cutting and finishing work.



No. 66 Single Surface, 6 roll planer for first cutting and finishing work.

No. 88 Double Surface, 8 roll planer for first cutting and finishing work.

No. 55 Heavy Duty Double Surfacer for planing rough lumber.



MICRO-SURFACER for planing hardboard and other very thin materials.

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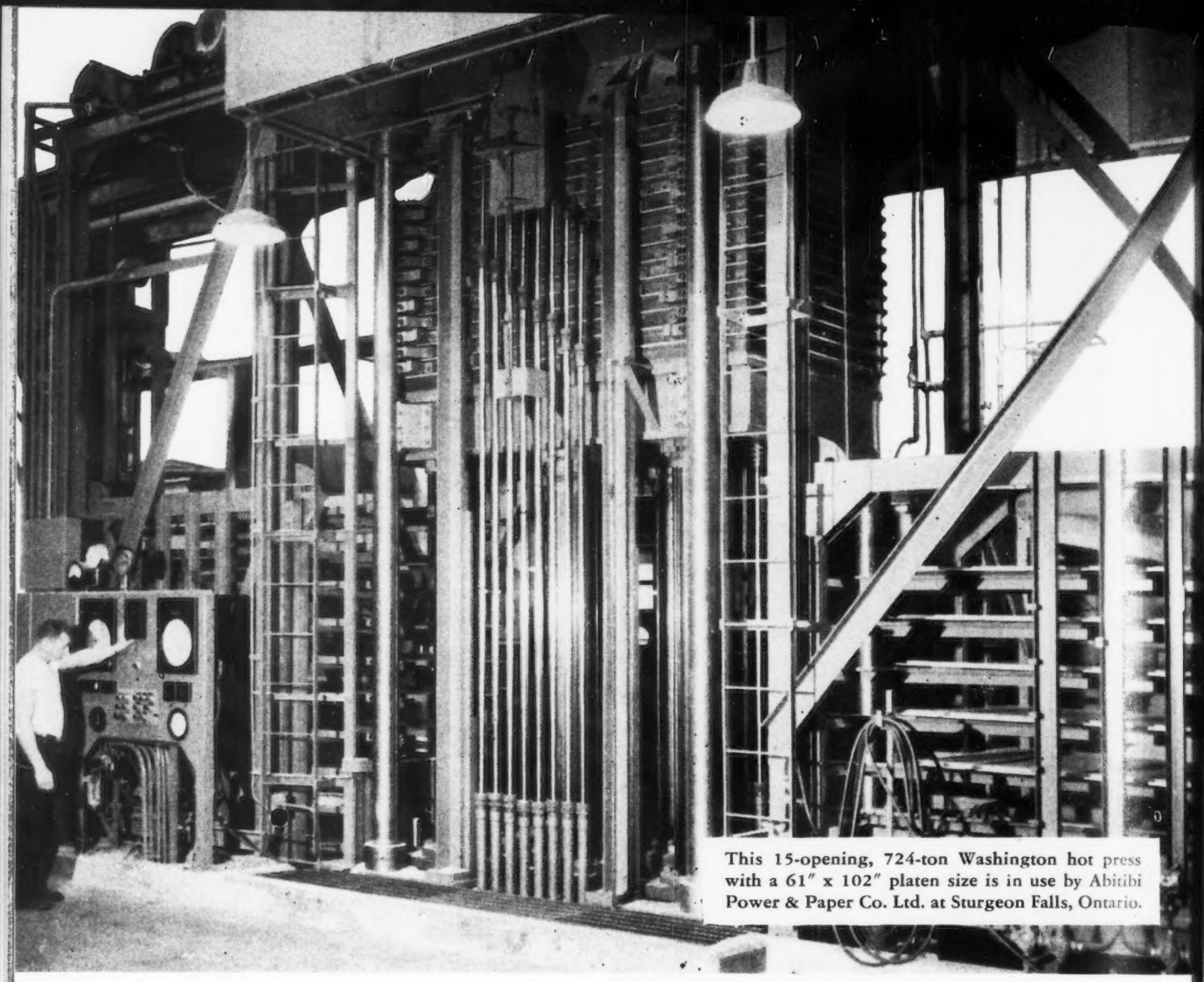

This 15-opening, 724-ton Washington hot press with a 61″ x 102″ platen size is in use by Abitibi Power & Paper Co. Ltd. at Sturgeon Falls, Ontario.

# Abitibi chooses Washington press to enter particle board field

**Washington multi-platen hot presses for hardboard or particle board production are in use or on order by the following:**

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AMERICAN PARBOARD CORP. Black Mountain, North Carolina
CAROLINA FOREST PRODUCTS INC. Wilmington, North Carolina
COLUMBIA HARDBORD CO. Everett, Wash.
GEORGIA-PACIFIC CORP. Coos Bay, Ore.
GRAY PRODUCTS COMPANY Waverly, Va.
JOHNS-MANVILLE PRODUCTS CORP. Natchez, Mississippi
MASONITE CORP. OF AUSTRALIA LTD. Eildon, Australia
POINSETT LUMBER & MANUFACTURING CO. Pickens, South Carolina
POPE & TALBOT INC. Oakridge, Oregon
TIMBER ENGINEERING COMPANY INC. Washington, D. C.

Each Washington press for forming hardboard, flake board or particle board is engineered to meet the complex requirements of the particular installation. Platen size, number of platens, size of opening, range of temperatures and pressures, and automatic cycle timing are designed to individual specifications to deliver the performance wanted in each instance.

Many plant and consulting engineers are specifying Washington-built equipment for complete board production lines. They know they can rely on Washington hot presses, loaders and injectors, ejectors and unloaders for efficient operation, uniform board quality and high production.

HOT PLATE PRESSES • AUTOMATIC PRESS LOADERS AND UNLOADERS • COMPLETE DRY PROCESS HARDBOARD FORMING EQUIPMENT AND SPECIAL MACHINERY

WASHINGTON IRON WORKS

**WASHINGTON IRON WORKS, 1500 Sixth Ave. South, Seattle 4, Washington**

We would like further information without obligation, on Washington hot presses and accessory equipment for hardboard, particle board and flake board production.

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Address _____

City _____ Zone _____ State _____

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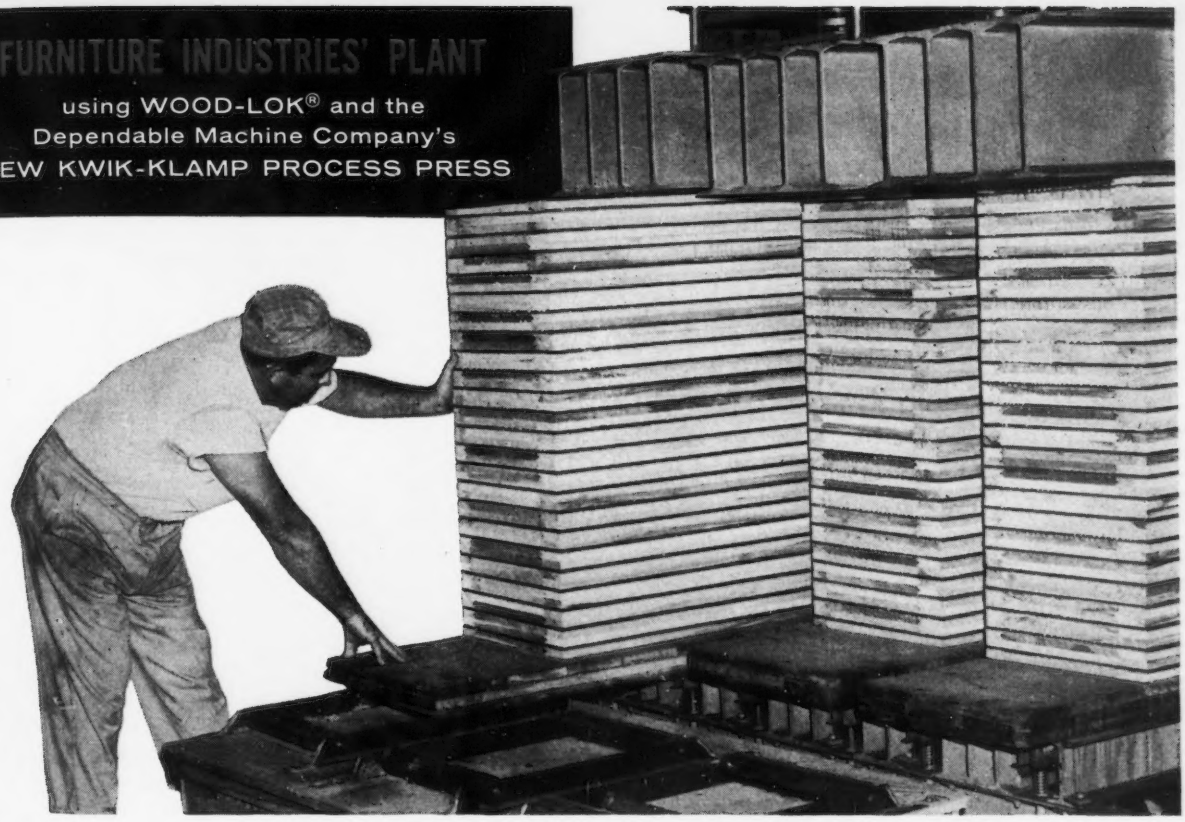
using WOOD-LOK® and the
Dependable Machine Company's
NEW KWIK-KLAMP PROCESS PRESS



# Saves 16 Man-Hours a Shift!

**NO CLAMPING** Furniture Industries' Plant for mass producing bedroom furniture in Florence, S. C., is now fully modernized. Costs are lower because WOOD-LOK, National's faster setting, stronger bonding glue, has completely eliminated unwieldy I-Beams and clamps. Production is faster because the Dependable Machine Company's New Kwik-Klamp Process Press handles three stacks at once, utilizing full press height. The result? Savings of 16 man-hours a shift.

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Increased production efficiency pays for new press in less than a year. Even pressure distribution reduces rejects. Lowest priced sectional press available. Sold exclusively by National.

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WOOD-LOK needs only a 15-30 minute press. Reaches machining strength in an hour or less instead of six hours or longer. Eliminates curing rooms as well as the cost of clamping.

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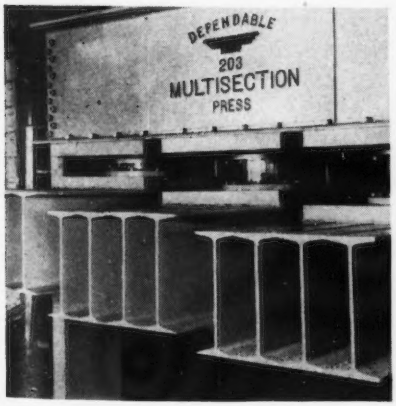
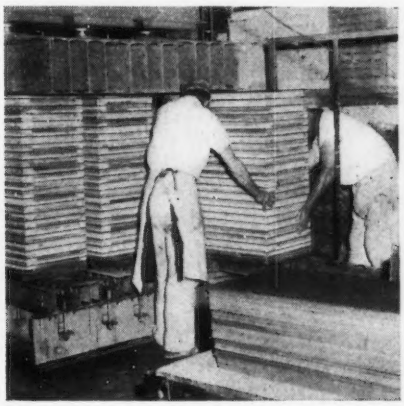
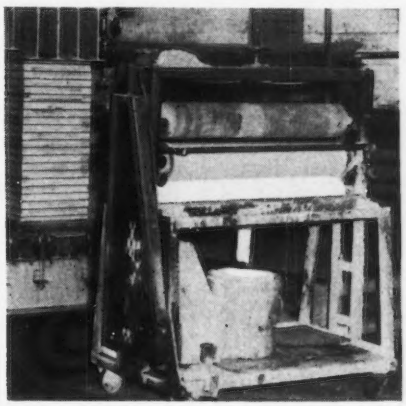
WOOD-LOK is an unmatched cold run resin glue that requiries no mixing or heating. Lasts all day in the pot. Cleans up readily with water. Nonirritating to skin. Virtually odorless.





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National
STARCH PRODUCTS INC.

INTERESTED? Ask to have one of National's Field Engineers tell you more about the time-saving features of WOOD-LOK and the NEW KWIK-KLAMP PROCESS PRESS.

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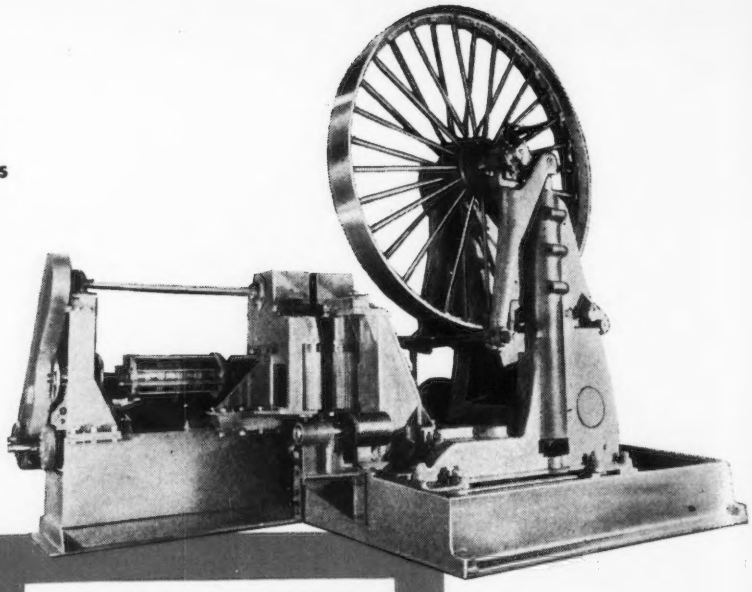
- **Automatic Push Button Setworks** — For instantaneous change between side and center sawing positions. Simply push a button to achieve any set desired.
- **Extra Heavy or Standard Feedworks**
- **Revolutionary New 2 or 3 Way Lumber Sweep Behind Vertical Saw** — Operated by the vertical resaw operator. Eliminates a man behind the resaw!

***Write for Bulletin No. 311***



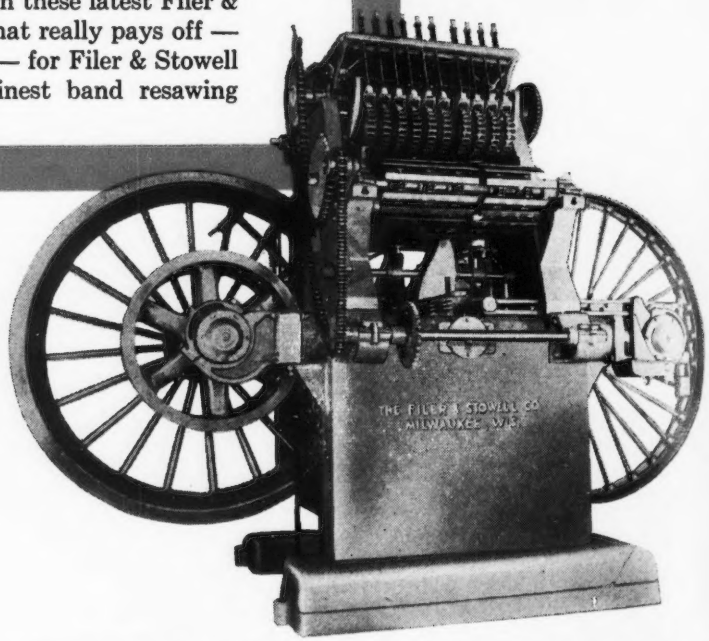
Filer & Stowell 8′ vertical resaw with 4 roll extra heavy feed works, arranged for instantaneous shifting between both side and center sawing positions.

## MORE PROFITS HIGHER PRODUCTION LESS DOWN TIME

**Only FILER & STOWELL RESAWS insure these EXTRA DIVIDENDS year after year!**

No other resaws can offer sawmill operators so many fine features — such assurance of high quality and dependability. All the newest developments and labor saving devices wanted by the industry have been incorporated in these latest Filer & Stowell resaws. They're an investment that really pays off — one that you can make with confidence — for Filer & Stowell has been manufacturing the world's finest band resawing machinery for 99 years.

Outfeed or rear view of Filer & Stowell 8′ Double Table Horizontal Resaw.




# FILER & STOWELL HORIZONTAL RESAW

**Available in 6′ or 8′ diameter wheels**

- **Furnished with either single or double tables which can be equipped with disappearing center guide and operated as a single table.**
- **Instantaneous finger lever control of tables**
- **Wheels partially below floor give greater visibility to operators and foremen**

***For complete details write for Bulletin No. 312***

## THE FILER & STOWELL COMPANY

147 E. Becher Street, Milwaukee 7, Wisconsin

**1856 A CENTURY OF PROGRESS 1956**

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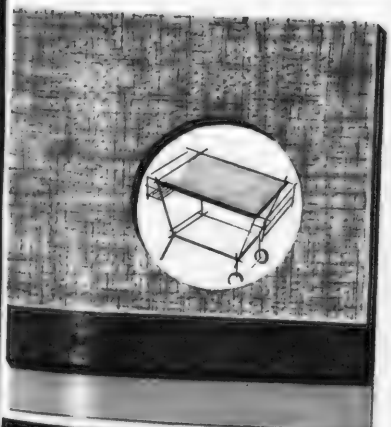
PANEL PRODUCTS

Aluminum and other thin-gauge metals are immeasurably strengthened with a Masonite hardboard core. Rigid and dense, it resists dents, absorbs shock.

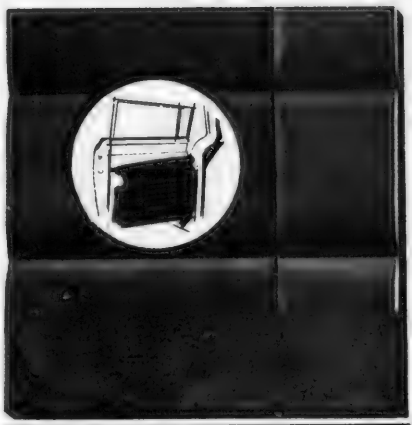
Colorful, cleanable porcelainized steel gains strength and stability with Masonite grainless panels for a core. They never split, splinter or crack. Resist moisture.

Expensive, exotic woods, veneered to Masonite panels, now enrich the value of many home and office furnishings—efficiently and economically. A designer's delight!

## *From metal to paper–Plastics to wood–Your best base for laminates*



Plastic laminates, in linen, wood grains and a variety of other finishes bonded to stable Masonite panels, create new standards of beauty and usefulness.



Many special laminates—vinyl, cloth, paper—may be bonded or fastened to these even-structured Masonite panels—the only complete line of hardboard . . . a type, thickness and size to meet your production requirements.

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**PROTEIN-LATEX** adhesives, combinations of Lauxein caseins and Lytron latex, set at temperatures right down to freezing. With Monsanto PROTEIN-LATEX adhesives and the NO-CLAMP* process, table tops, doors and the most difficult to glue surfaces can be efficiently mass produced using shorter pressure periods and less time, space and equipment. Curing rates are easily adjusted with changes in formulation or spread rate.

PROTEIN-LATEX adhesives are easy to mix and they have a long working life. They are gap-filling, self-bonding and excellent for rough cut veneers. Bonds made with PROTEIN-LATEX adhesives are unusually durable and water resistant.

For technical data on Monsanto PROTEIN-LATEX formulations, write to Monsanto Chemical Company, Plastics Division, Room 1644, Springfield 2, Mass.

*Other outstanding Monsanto Adhesives are:*

**LAUXITE MF-300** *A melamine adhesive for hot press, colorless waterproof bonds.*

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**LAUXITE MF-325** *A specially formulated powdered melamine resin binder for granulated wood.*

**RESINOX** *Phenolic resins, liquids and compounds, for granulated wood molding and hardboard.*

**LAUXITE UREA** *Resin glues, both liquid and powder, for high water resistant bonds.*

MONSANTO

FPRS NEWS-DIGEST

Volume VII JUNE, 1957 Number 6

# WELLS' GIFT TOPS FPRS BUILDING FUND DRIVE

## A Number of Large Contributions Reported as Drive Nears $13,000

The largest single contribution to date in the drive for the proposed new FPRS Executive Office building in Madison, Wis., has been made by John E. Wells, president, Wells Furniture Manufacturing Co., Laurel, Miss. Mr. Wells has given wood office furniture valued at $3,000 and has offered to supplement this with additional pieces valued at $1,000 when the proposed building is completed.

Presently in use in the Society's temporary offices in Madison (see cover), the 32 pieces contributed by the Wells company consist of three suites of walnut executive furniture, for the offices of the Executive Secretary and Editor, and five groups of contrasting general office furniture in softone oak. Included are 8 desks, 6 tables, and 18 matching chairs.

In making the presentation, Mr. Wells supported with action his belief in the importance of research as insurance for the wood industry's future. He thus recognizes the Society's role in this long-range program, through dissemination of wood technology at its meetings and in its publications.

### Former Section Chairman

Long active in FPRS affairs, Mr. Wells served in 1956 as Chairman of the Mid-South Section, covering the states of Mississippi, Louisiana, Tennessee, Oklahoma, Texas, and Arkansas. Under his leadership, the Section held its most successful meeting last fall in Laurel, with more than 125 persons attending.

Mr. Wells' contribution brings to nearly $13,000, including $10,000 in cash pledged or contributed towards the building since the start of the current fund-raising drive January 1. R. T. Berry, chairman of the 35-member nation-wide team working on the campaign, will report its present status during the National Meeting late this month.

JOHN E. WELLS

The third phase of the drive, already underway, is mailing of personal letters from Section Chairmen to all members, enclosing a brochure describing the proposed building and outlining the need for contributions. It is hoped that individual members will respond in such amounts as they deem desirable.

### Other Major Contributions

Pledges or contributions in major amounts have also been received in recent weeks from the following:

Breece–White Manufacturing Co., Eudora, Ark., $50

Buckman Laboratories, Memphis, Tenn., $100

R. S. Burruss Lumber Co., Lynchburg, Va., $50

Carolinas–Chesapeake Section, FPRS, $150

Chapman Chemical Co., Memphis, Tenn. and Portland, Ore., $200

Diamond Match Co., Chico, Calif., $1,000

Gamble Brothers, Louisville, Ky., $200

E. S. Harrar, Durham, N. C., $50

Ivory Pine Co., Dinuba, Calif., $500

L. D. Kellogg Lumber Co., Alexandria, La., $100

Klamath Equipment Co., $170

Arthur D. Little, Inc., Cambridge, Mass., $50

Ohio Valley Section, FPRS, $100

Oliver Machinery Co., Grand Rapids, Mich., $100

Poinsett Lumber and Manufacturing Co., Pickens, S. C., $1,000

Scott Lumber Co., Burney, Calif., $1,000

Ralph L. Smith Lumber Co., Anderson, Calif., $1,000

U. S. Plywood Corp., New York, $1,000

Weyerhaeuser Timber Co., Tacoma, Wash., $1,000

Architect's drawing of proposed FPRS Executive Office Building.

# New York College Dedicates $3.75 Million Laboratory

Designed for education and research in forest products, the $3.75 million Hugh P. Baker Laboratory at State University of New York College of Forestry was dedicated May 2 and 3.

## Nation's Newest Center for Forest Products Research and Education Is Opened

"Ushering in a new era in research in the wood-processing industries," according to one speaker, the new Hugh P. Baker Laboratory at State University of New York College of Forestry, Syracuse, was officially dedicated last month. The newest education-research center of its type in the nation, the building is named in honor of the College's first dean, the late Dr. Hugh P. Baker.

"Forest Products in Today's World" was discussed by a five-man panel at the opening of the exercises May 2. A banquet was held that evening and the $3.75 million building was officially opened the next morning.

General chairman for the exercises was alumnus F. S. Crysler, manager, Eastern Division, Container Corp. of America. Speakers at the opening symposium were Chairman, Clyne Crawford, president, Crawford Furniture Corp.; Richard E. McArdle, chief, U. S. Forest Service; S. W. Antoville, president, U. S. Plywood Corp.; O. H. Alderks, vice-president, Buckeye Cellulose Corp.; and George A. Garratt, dean, Yale School of Forestry.

David L. Luke, Jr., president, West Virginia Pulp and Paper Co., and president, American Pulp and Paper Association, was principal speaker at the dedication banquet. Frank C. Ash, president of the College's board of trustees, was toastmaster. Other banquet speakers included: Judge Francis D. McCurn, past president of the College trustees; Chancellor William P. Tolley, Syracuse University; and Hardy L. Shirley, College of Forestry dean.

New York's Governor Averell Harriman was principal speaker at the dedication ceremonies May 3. The official ribbon cutting to open the building was by Mrs. Hugh P. Baker and Mrs. Richard N. Wright, daughter of the late dean. They were introduced by Dr. J. S. Illick, dean emeritus of the college.

### Research Facilities

The new laboratory has a gross area of 120,000 square feet. Constructed principally of reinforced concrete with interior walls of structural tile, the building is four stories high with a one-story shop wing.

Experimental rooms include five wood-conditioning rooms, 13 temperature-humidity controlled labs, two refrigerated rooms, two vibration free areas, and 14 explosion-proof rooms. The building also contains four classrooms, 26 faculty offices, 22 graduate student offices and labs, three libraries, and 70 teaching and research laboratories.

Set up to handle any problem in wood research from the log through to marketing of the finished product, the laboratories contain some of the finest testing facilities in the nation. Baker lab, for example, is the only wood science center in this country with an electron microscope. The latter can magnify an object up to 100,000 times actual size.

Equipment for testing properties of wood samples from a match stick to mammoth girders is included. Load capacities from two grams to 40,000 pounds may be applied.

### Sawmill Equipment

In the experimental sawmill the circular saw speeds can be varied from 50 to 1,150 rpm. Gauges measure forces, speeds, and torques, permitting a wide range of studies in lumber manufacturing.

The carriage is a standard left hand model, except for some special features. There are four headblocks, each with set-out mechanism to permit sawing tapered logs parallel to the bark line, and duplex dogs which can be used to hold any shape of log or cant.

The mill's sawing accuracy is 1/64 inch, with double acting setworks consisting of machined ratchets, pawls and gears actuating the knees through the setshaft. Designed to have one or

Prof. K. C. Compton instructs students in instrumentation for determining forces required during sawing of logs with 52-inch circular headsaw.

Machining research laboratory is fitted with special woodworking equipment with operating speed ranges covering present and probable future industry conditions. Force, power, and torque measuring instruments permit detailed study of mechanics of wood cutting processes.

graduate assistant adjusts automatic recorder-controller for one of steam-heated kilns as Prof. R. J. Hoyle looks on. Instrument panel contains all operating and recording devices for four kilns, including variable speed fan controls, 48-station potentiometer, steam flowmeter, steam pressure recorder, kil-mo-trol, relays, switches, and timers.

more operators on the carriage, the mechanism may be modified so the sawyer can do the setting, reverse the knees, and dog the logs.

### Five Dry Kilns

The new laboratory has a battery of five dry kilns, four with a capacity of 1,000 board feet each and one with a capacity of 4,000 feet. Incorporating the latest design features, the kilns permit maximum flexibility for both teaching and research purposes. Four of the kilns are equipped with variable speed internal-fan systems with air velocities from 100 to 800 feet per minute. Two units have four-speed short-shaft internal motors designed to operate under high temperature and humidity conditions. The other units contain long-shaft fan systems with four-speed external motor drives.

One unit is a combination gas- or oil-fired system which can utilize direct or indirect combustion products. Three kilns are steam heated and the fifth will be held available for future equipment installation when new effective design warrants its inclusion. All units are designed for variable steam pressure so that high and low pressure steam usage can be evaluated under actual operating conditions.

The versatile wood preservation lab has five impregnating cylinders, the largest of which is 12 feet long and 4½ feet in diameter. Pressure up to 1,000 psi is obtainable in one cylinder. In the basement, preservatives are stored in nine 1,000-gallon tanks and one 1,500-gallon sump tank.

The woodworking facilities consist of two laboratories, one for instructional purposes and the second containing equipment and instruments for machining research. A 24-inch planer, 12-inch jointer, and 16-inch table saw have direct current motors with variable speed control permitting operation at speeds ranging from 880 to 14,400 rpm. The single spindle shaper is a four-speed machine ranging from 2800 to 8000 rpm. A multiple speed variable rate hydraulic feed drill unit is available for research in wood boring and similar operations.

Dynamometers and strain gauge analyzers are provided for measuring the forces involved in cutting operations. Potentiometers for temperature measurement, tachometers, work feed unit, graphic wattmeter, and other cutting and measuring tools round out the facilities.

High speed photographic equipment is available for the study of cutting phenomena. In addition to grinding room facilities, the researchers also have access to metalworking machinery and heat treating equipment.

### Finishing Facilities

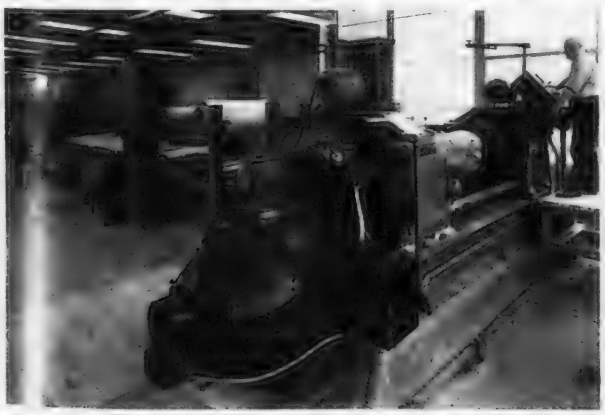
The wood finishing facilities of the new laboratory consist of four connecting interrelated units. The mixing room contains a variety of testing devices for determination of non-volatiles, density, drying time, viscosity, wet film thickness, and other physical and chemical properties of finishing materials. The spraying room, with both water-wash spray booth and a dry booth, is designed for demonstration and investigation of airless steam and electrostatic spraying, roller coating, dipping, and tumbling techniques.

Prof. W. A. Cote explains operation of the electron microscope to Gov. Averell Harriman; Judge Francis D. McCurn, past president of trustees; Dean Hardy L. Shirley of forestry college; and W. S. Carlson, president, State University of New York.

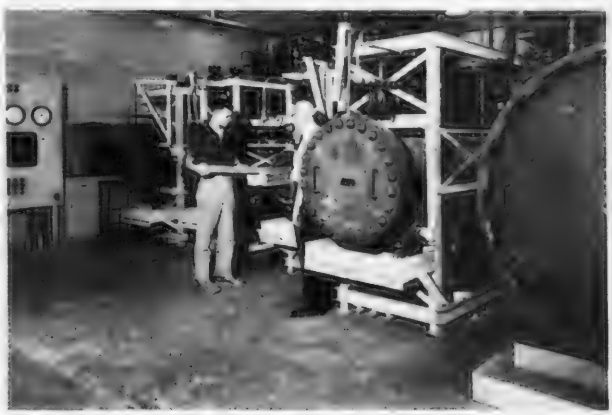
The drying room has an 8 cubic foot testing cabinet with temperature control from −60° F. to 400° F. The room is equipped with portable sample drying racks and infra-red banks to permit development work in infra-red drying. The testing room is designed for physical testing of dry finish films. Included is an atlas twin-arc weatherometer and a variety of apparatus for determining physical properties of finishes.

The veneer and plywood laboratory has a 54-inch veneer lathe, operated by a d.c. variable speed motor. The lathe has a swing of 36 inches and may be operated at speeds from 300 to 1200 rpm. The conveyor operates at approximately 25 feet per minute and the veneer clipper up to 250 strokes per minute.

The veneer dryer, operating at 6 to 96 inches per minute, is steam heated



erating 54-inch rotary veneer lathe is Prof. A. H. Bishop, right, wh student at left rear operates electrical switches activating wet cl r knife.



Prof. Bishop explains operating techniques of wood preservation lab to student. Varied-size timber can be impregnated with preservatives in this versatile facility.

Dr. Carl H. deZeeuw, left, and graduate student R. W. Davidson test a prefabricated wall panel in the 400,000 pound testing machine.

and the splicer can be operated between 15 and 85 feet per minute. The plywood press, with steam heated platens, will produce pressures up to 500,000 pounds.

Features of the mechanics and physics laboratory include isolated slabs, one of which is suspended on springs, with the others having independent foundations to bed rock. A special conditioning room is suspended entirely on springs. Universal testing machines can apply pressures of 5,000 pounds, 50,000 pounds, 120,000 pounds, and 400,000 pounds.

Other special facilities include rooms where temperature can be varied from 100° below to 200° above zero and humidity from 0 to 100 per cent, x-ray machines for detecting and measuring crystals, mass spectograph and recording spectrophotometer, and an automatic paper coating machine that applies plastic and other finishes to paper.

Housing three departments of the College—forest utilization, wood technology, and forest chemistry, Baker Laboratory is said to affirm New York State's intention to respond to and aid acceleration of research activity. As pointed out by Gov. Harriman, "increasingly informed and dedicated men, and their exploration on the frontiers of knowledge, are needed by our country and by a world vitally dependent upon the forest and its products."

## Five-Man Panel on Forest Products in Today's World Opens Dedication Exercises

"This laboratory will have a tremendous effect on the furniture industry as well as other wood industries," said Clyne Crawford in opening a symposium on "Forest Products in Today's World" at last month's dedication of the Hugh P. Baker wood products laboratory at Syracuse.

"Research is generally considered an investment in future progress, not in today's operations," pointed out Crawford, past president of the National Association of Furniture Manufacturers and trustee of the Syracuse forestry college. "The new laboratory will serve the research needs of small companies, which are the heart of American industry and which cannot generally afford an investment in future progress."

The furniture industry, one of America's largest, is made up of more than 3,000 companies, Crawford stated. Of this number, not more than 12 have a sales volume exceeding $10 million annually. "The test of increasing furniture sales in the future will depend upon research to reduce costs and make products available in greater abundance to more people."

S. W. Antoville, president of U. S. Plywood Corp., cited several examples of the trend to integration in the forest products industry. "Companies are able to conduct a variety of wood processing activities at the same location or in the same area," he said, "thus making good strides towards more complete utilization of raw materials of the forests."

"A far greater emphasis upon research is among the benefits already showing up from integrated operations," the plywood executive continued. "Research has become a necessity for industry to compete and survive. From the intensified research programs which are being developed, we shall see new wood products which will enrich the daily lives of all people."

Particle board has been one of the most important developments in the wood industry in the last decade Mr. Antoville added. "We are just beginning to exploit this important development. The field for research here is tremendous and many products not now dreamed of will develop from the laboratories of industry and forestry schools."

### Training Industry Leader

"Education for Forest Products Leadership" was discussed by Yale Dean George A. Garratt, a past president of FPRS. "One of the justifiable major criticisms of educational programs in forest products," he pointed out, "is that, far too generally, schools have been training men for subordinate jobs without really attempting to equip them to meet future opportunities for advancement to positions of major responsibility. What is needed is a strengthening of the concept of Education for a Profession rather than Training for a Vocation."

Pointing out the growing opposition to emphasis on specialization in many professional fields, the Yale Dean noted the strong reaction in favor of increasing standards in general education. He cautioned that there is an element of danger in any marked swing toward general education if it is at the expense of adequate technical training.

Emphasizing that only a restricted number of graduates will attain positions of leadership in the forest products industry, Dr. Garratt said the future leaders will be those who have breadth of outlook, who develop a personal fervor and dedication to the purposes of the industry, who have the capacity to understand the many facets of the business, and who can develop an appreciative concept of their organization's basic philosophy.

"The development of future leaders in this field must be shared to the fullest extent by industry, he con-

S. W. Antoville, president of U. S. Plywood Corp., speaking during opening symposium of Hugh P. Baker laboratory dedication ceremonies. From left to right are: O. H. Alderks, Clyne Crawford, F. S. Crysler, R. E. McArdle, and G. A. Garratt.

ti ed. "Companies must supplement ac demic preparation with an appro- p te training-within-industry pro- g n, thus helping relieve the pressure o schools for continued vocational- ty instruction."

Proper balance is needed in evalu- at g the true significance of innova- ti s suggested in forest products e cation," Dean Garratt concluded. " ducational programs must be d mic, geared to the constantly in- cr sing standards of general and pro- fe ional education, and responsive to i ortant shifts in methods, policy, or e hasis. If forest products training is to meet the challenges of the future, it m st be clearly established on the pro- fe ional level."

### Key to Forest Management

Richard E. McArdle, Forest Service chief, urged that the new laboratory be used to develop better forest products utilization, and thus make forest products the key to forest management.

"The possibility of selling what is grown provides the incentive for making forest lands productive," Mr. McArdle pointed out. "Knowledge of the kinds of finished products in demand answers the question of what to produce—the choice of species and rotation. Use of thinnings, tops, short lengths, and defective trees will help smooth the way toward better integration of wood-using industries."

He emphasized that quantity of timber available in the future and timber quality are closely related. One aspect of the problem of declining timber quality is to make the present supply go further, the U. S. F. S. chief continued. Another is to find uses for low-value trees, especially hardwoods, and help forest ownerships become fully productive. "The key that will unlock this door will advance progress in forest management while adding greatly to the wood supply of the future."

### Importance of Basic Research

Representing the cellulose industry, O. H. Alderks, vice-president, Buckeye Cellulose Corp., discussed University-Industry Research in Cellulose Products. Reviewing a few highlights of scientific progress in the last four decades, he pointed out that progress in applied science has been dependent upon basic research.

Creation of the new Cellulose Research Institute at the Syracuse college represents an important step toward increased support in basic research at universities," Alderks asserted. "It will serve as a central source of fundamental knowledge serving as a basis for industrial growth and development."

JUDGING 1957 AWARD OF MERIT contest entries are: Harold Aranda, Fastener Corp.; Charles Devlin, National Plywood Distributors Assoc.; Frank Slauf, Slauf Advertising; and Frank J. Rovsek, FPRS Executive Secretary. Sponsored by Hitchcock's Wood Working Digest, the contest publicly commends firms, associations, and schools promoting better understanding of wood utilization. Awards were presented June 24 at the FPRS National Meeting in Buffalo.

## NLMA Expanding Research and Promotion Activities

The stage was set for possible expansion of the lumber industry's research, merchandising, and wood school promotion efforts at the spring meeting of directors of National Lumber Manufacturers Assoc. in Boston last month. The board discussed all three projects and directed the association's Executive Committee to take up specific proposals at a meeting later this year.

W. J. EASON

A highlight of the three-day meeting, May 13–15, was a panel discussion of the factors responsible for the growing popularity of one-story wood schools. Architect-lumberman W. Jeter Eason, FPRS President-Elect and one of the panelists, attributed much of the increased popularity to their economy and flexibility of design.

Eason underscored several obstacles that the lumber industry must overcome in promoting wood school construction. He also acclaimed wood's versatility, describing it as "excellent" for use as cabinets and space dividers, decorative panels, and built-in furniture and equipment.

George M. Rideout, noted business analyst and vice-president of Babson's Reports, Inc., predicted that the physical volume of business this year will be at least the second best on record and may equal last year's all-time high. He looks for generally good times to continue for the next decade but warned that demands for higher wages and shorter working hours could set off a recession earlier.

## Michigan Plans Furniture "Trouble Shooting" Course

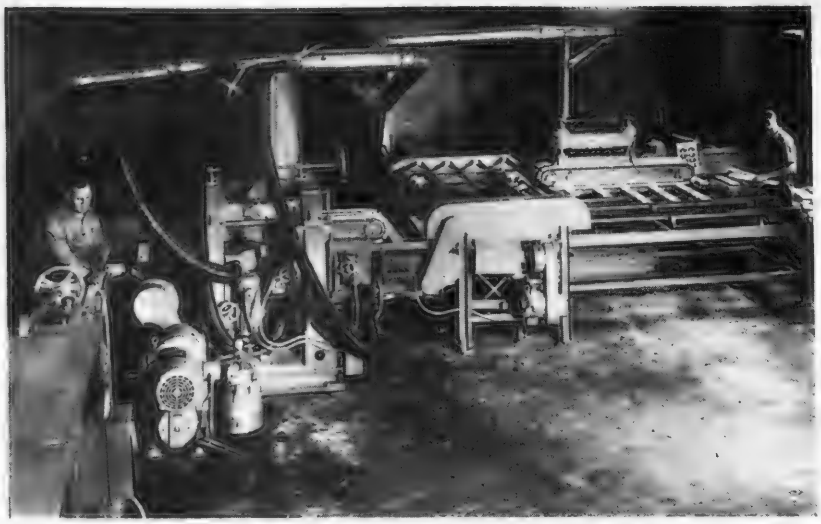
The sixth annual course, "Trouble Shooting in the Wood-Furniture Industry", will be held at the University of Michigan, Ann Arbor, Aug. 5–10. Offered by the Department of Wood Technology and the Summer Session and Extension Service, the course emphasizes analyses of actual production and service rejects to determine the cause of problems and preventive measures that could have been taken.

Through lecture, demonstration, and laboratory practice, the course covers wood structure and properties, drying, gluing, machining, and finishing as they relate to mis-manufactured and unserviceable parts. Time is available for individual consultation with staff members on specific problems.

Enrollment is limited to 18 persons, with applications accepted in the order received. Advance registration is necessary and may be made with the Institutes Department, Extension Service, University of Michigan, Ann Arbor. The fee of $125 per person should accompany the application.

## Weyerhaeuser Co. Receives Top Honor for Advertising

The wood industry's public relations program received a nation-wide pat on the back in April when Weyerhaeuser Timber Co. and its advertising agency, Cole & Weber, received one of the nation's top honors for their current advertising program. The SATURDAY REVIEW's annual advertising committee selected a Weyerhaeuser advertisement, one of a series,



NEW FINGER JOINTING equipment will be demonstrated in operation at Greenlee Bros. & Co., Rockford, Ill., during July and August.

as "the most distinguished public-interest advertisement of the year."

In its April 20 issue, the magazine had this to say about the advertising program, "The Number One advertisement of the year is from Weyerhaeuser's handsome, full-color campaign on behalf of tree farming as the modern method for insuring a permanent supply of wood for America. This campaign has not only aided conservation and the efficient use of our timberlands, but has dramatized the importance of regarding trees as crops to be scientifically planted and harvested, thus protecting this country against any future exhaustion of its invaluable timber resources."

### Greenlee Schedules Plant Demonstrations of Equipment

Working demonstrations of their new finger-jointing equipment will be conducted at the plant of Greenlee Bros. & Co., Rockford, Ill., during July and August. Visitors will see how this equipment machines, glues, assembles, and electronically cures the joints in a continuous operation. They will also see the assembled stock automatically cut to predetermined lengths after being joined.

Clinic sessions will be conducted by Greenlee sales and engineering personnel in conjunction with the demonstrations. They will explain in detail how the finger-jointing equipment upgrades dimensional lumber and utilizes short lengths. Representatives of firms supplying adhesives and electronic curing equipment used in the process will be present.

Greenlee officials have invited anyone interested in finger-jointing to attend the demonstrations for one or two days. Arrangements may be made by contacting D. B. Perkins of the woodworking sales department.

### DuBrucq Re-Elected President of Machinery Manufacturers

R. C. DuBRUCQ

Ray C. DuBrucq, Rockwell Mfg. Co., was re-elected president of the Woodworking Machinery Manufacturers Assoc. at the annual meeting in April at Southern Pines, N. C. Other officers are: L. H. Geddes, Greenlee Bros. & Co., vice-president; E. J. Bell, Jr., Bell Machine Co., secretary; and F. G. Walker, Jones Superior Machine Co., treasurer.

Five members of the Southern Furniture Manufacturers Assoc. presented a panel discussion on "What We Expect from the Woodworking Industry." The discussion covered the fields of safety, fast set-up equipment, automatic feeding and unloading mechanisms, and machinery manufacturers' service. They also described specific new machines needed to reduce costs and increase production.

Plans for the American Woodworking Machinery and Equipment Show to be held May 13–17, 1958, at Winston Salem, N. C., were reported by R. F. Hall, Jr., Wysong and Miles Co. Officers for the show are: Mr. DuBrucq, president; Doak Finch, Thomasville Chair Co., vice-president; and W. M. York, Newman Machine Co., secretary-treasurer.

### Introduce New Fiber Board Made from Minnesota Aspen

Minnesota and Ontario Paper Company's Insulite Division has developed a new fiber board which was introduced to the building industry recently. Paul A. Mahony, Mando's vice-president in charge of sales, said the product is called Insulite Primed Siding. The board is made from Minnesota native aspen at the firm's International Falls mill.

### Tungsten Carbide Tools Demonstrated at Sheboygan

R. V. REYNOLDS

Wisconsin wood products manufacturers were given an educational program and demonstration of tungsten carbide tools in Sheboygan, Wis., in May. The meeting was conducted by R. V. Reynolds, manager of woodworking sales, Kennamental, Inc., who discussed cemented tungsten carbide as a material, its uses, and its applications to existing woodworking machinery.

Motion pictures of "Tungsten Carbide for Woodworking" followed a buffet dinner. Mr. Reynolds then spoke on "Grinding and Maintenance of Carbide." The group of 55 persons was then taken to Phoenix Chair Co., Sheboygan, for a demonstration of planing with solid Kennametal knives.

Companies represented in the group included Lullabye Furniture Corp., Curtis Companies, Inc., Edison Wood Products, Paine Lumber Co., Unit Structures, Connor Lumber and Land Co., Hamilton Manufacturing Co., Algoma Plywood and Veneer Co., A. A. Laun Furniture Co., Rway Corp., K. W. Muth Co., American Chair Co., Martens Manufacturing Co., Ebenreiter Wood Working Co., Harnischfeger Corp., Buckstaff Corp., Richardson Bros. Co., Leick Furniture Co., and Phoenix Chair Co.

### Formaldehyde Plant Opened in Fayetteville, N. C.

The firm's second southern formaldehyde and resins plant was opened by the Borden Co. at Fayetteville, N. C. recently. Geared to produce 30 million pounds of formaldehyde annually, the plant was formally activated by A. R. Marusi, president of the company's chemical division, at ceremonies attended by company executives and civic and industrial leaders from the southern area.

From the formaldehyde, the plant will also make urea resins for the plywood, furniture, and woodworking industries; wet strength resins for the paper industry; and resins for printing and finishing textiles. The plant also serves as a warehouse for polyvinyl acetate and polyvinyl alcohol for the textile, paint, and adhesives industries.

## Outstanding Ohio Valley Section Meeting Held in Louisville

The invigorated Ohio Valley Section under the able leadership of Chairman John H. Wilson, Wilson Bros., Indianapolis, held the most successful Spring meeting in its history April 11 and 12 in Louisville, Ky. More than 60 persons registered for the meeting, held in the Kentucky Hotel.

C. D. Dosker, president, Gamble Bros., Louisville, delivered the keynote address on the subject, "A Critical Look at Today's Lumber." He noted that the quality of hardwood sawtimber is declining annually, resulting in less production of common and better grades of lumber, with corresponding increases in residues. He recommends greater education to dispel the practise of buying No. 1 common and better lumber because of "tradition," emphasizing that often needs can be met with lower grades at a savings in cost. Dosker predicted that unless some answer can be found to better utilization of the products of the sawmill, board lumber as we know it will become a by-product of fiber operations.

Highlighting the meeting were the five round-table discussions covering lumber handling and drying, carbides, jigs and fixtures, particle board, and gluing. Registrants were able to discuss their individual plant problems with a panel of experts in small, committee-type "huddles." The technique proved so successful from the standpoint of both manufacturers and suppliers that the general concensus was to hold more meetings of this type in the future.

Reports of the panel discussions, as well as Mr. Dosker's address, are being considered for publication in the JOURNAL.

A trip through the H. J. Scheirich plant, manufacturers of kitchen cabinets, concluded the meeting. Of special interest was the modern materials handling system and the use of unique species of domestic hardwoods.

## Fourteenth FPRS Section Formed in Rocky Mountains

The 14th Section of the Society, the Rocky Mountain Section, was formed at a meeting May 6 at the Cosmopolitan Hotel, Denver, Colo. The new Section now numbers some 30 members in the states of Colorado, Utah, and New Mexico. On hand to aid in the inauguration exercises were President Ralph H. Bescher, Pittsburgh; Southwest Regional Board Member R. H. Berry, Burney, Calif.; and Northern California Section Past Chairman H. N. Stephenson, Sacramento, Calif.

JIGS AND FIXTURES IN WOODWORKING was subject of panel discussion at Ohio Valley Meeting. Discussion moderator was William Lakamp, Baldwin Piano Co., Cincinnati, Ohio.

GLUES AND GLUING panel at meeting in Louisville was moderated by J. F. Habig. At right rear is R. L. Hiller, North-Central Regional Board member, principal luncheon speaker at meeting.

LUMBER DRYING AND HANDLING discussion was led by Ed Jones, National Cash Register Co., Dayton, Ohio.

PARTICLE BOARD AND WOOD CORES was subject of panel discussion moderated by Carl Seng, Jasper Desk Co., Jasper, Ind.

SIDE CUTTER USE AND MAINTENANCE was discused by panel moderated by J. R. Young, Oliver Machinery Co., New Albany, Ind.

KEYNOTE ADDRESS was given by C. D. Dosker (left), president of Gamble Bros., Louisville. Meeting concluded with tour of H. J. Scheirich cabinet plant.

Mr. Stephenson outlined the functions of a Section and the duties of officers. He also described the various types of membership and the distribution of fees between the National Office and Sections.

The history and value of the Society was discussed by Mr. Berry, who pointed out that membership was well balanced between industrial and technical people. He also reviewed model Section By-Laws and suggested the new Section consider these for adoption.

President Bescher gave an illustrated talk on the organization and major structure of the Society. He traced the history and growth of the organization and pointed out the need for the proposed new executive office building in Madison, Wis.

L. A. Mueller discussed "Present and Future Utilization of Forest Products in the Rocky Mountain Area" on the afternoon portion of the program. W. R. Fritze concluded the meeting with a talk on how wood preservation has contributed in the overall role of better wood utilization.

Permanent officers elected for the coming year included: T. W. Schomburg, forest products consultant, Denver, Chairman; W. R. Fritze, Koppers Co., Inc., Denver, Vice-Chairman; L. A. Mueller, U. S. Forest Service, Fort Collins, Colo., Secretary-Treasurer; J. S. Weidman, Weidman Lumber Co., Durango, Colo., Trustee (1 year); and H. E. Troxell, Colorado State University, Fort Collins, Trustee (2 years).

## FPRS Salutes . . .

**Men Contributing Time and Efforts for Furtherance of the Society and Wood Industry**

R. C. RIETZ

**Ray C. Rietz**—Presenting latest information on better seasoning practices and promoting the work of FPRS as well has been a monthly activity of Ray Rietz for more than four years. As editor of the FPRS Wood Drying Newsletter, Ray abstracts papers or articles on new developments in the seasoning field. More than 2500 copies are sent monthly to members of 21 dry kiln clubs and associations, laboratories in other countries, forestry school libraries, and the Library of Congress. Ray initiated the Newsletter in April 1953 while chairman of the FPRS Wood Drying Committee. A graduate of Beloit College, he was employed at a Mississippi sawmill before joining the staff of the U. S. Forest Products Laboratory in 1928 as a research engineer. Now in charge of kiln drying research, he has written numerous articles on wood seasoning practices. A frequent contributor to Section and National Meetings of the Society, Ray moderated a panel discussion at the 11th National Meeting in Buffalo this month.

J. J. ALLEGRETTI

**Joseph J. Allegretti**—As chairman of the Section Officers Advisory Committee at the National Meeting in Buffalo, it was Joe's job to preside at a meeting of section officers from throughout the U. S. and Canada. They consulted on problems affecting the sections and the national organization, and made recommendations to the National Executive Board. Joe is currently chairman of the Midwest Section, having previously served as secretary and vice-chairman. A graduate of the University of Idaho, Joe was associated with T. J. Moss Co., Signal Corps Radar Laboratory, Northern Aeronautical Corp., and Twin Cities Testing and Engineering Lab before joining Masonite Corp. in 1947. He is now director of product development and market research for Masonite in Chicago.

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## EMPLOYMENT SERVICE

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

### Positions Offered

No. E-271—Midwest millwork firm has opening for project engineer to be responsible for design and development of products. Needs man with B.A. in architecture or architectural engineering, interested in product design. Salary based on experience and ability; profit-sharing plan. (June)

No. E-274—Time standards man or industrial engineer sought by Midwest firm to assume responsibility in the field of methods study, motion and time study, and rate setting. (June)

No. E-275—Building products manufacturer in Midwest seeks mechanical engineer for design and development of minor production equipment, jigs, and fixtures for use in manufacturing operations. Must hold engineering degree from school of recognized standing. Should have knowledge of machine shop practices and fabrication methods as well as an interest in machine design. Salary based on applicant's experience and capacity for design and production engineering. (June)

No. E-278—Established lumber producer in Idaho has opening on products development staff. Needs man with experience or extensive knowledge in gluing techniques and/or structural engineering. Possibilities for administrative position in future utilization plants. Salary based on experience and ability. In reply, give age, experience and when available. (June)

### Employment Wanted

No. 414—Iowa State College graduate, B.S. in forestry (wood technology option) seeks wood technology or production position in Midwest or eastern U. S. Will consider sales work. Eight months experience in sales for lumber importers. Age 22, available for employment in June. (June)

No. 416—Indiana University graduate, age 41, seeks position as plant manager, assistant plant manager, chief industrial engineer or production manager in plant having production, cost, or supervisional problems. Past experience in position of plant industrial engineer and chief industrial engineer provided familiarity with methods, layout, machinery, material field, quality, personnel, standard cost, incentives and the solving of supervisional problems. Will locate anywhere. (June)

No. 417—Student, 21, seeks summer job in eastern U. S. in plywood or building board industry. Interested in research. Available for employment June 5. K. K. Blixt, 67 Cedar St., Morrisville, N. Y. (June)

No. 418—Alabama Polytechnic Institute graduate, B.S. in wood utilization, seeks position in wood products field. Main interest in sawmilling, wood preservation, timber procurement, gluing, and wood seasoning. Presently completing a two year tour of duty in Army. Age 24, married, prefers Gulf states, Southeastern U. S., or Colorado. (June)

No. 419—Graduate forestry engineer, age 34, married, seeks management position with opportunities for advancement. Experience in forest management, logging road construction, sawmill, box factory, particle board plant, lumber and particle board sale. (June)

No. 421—Forest utilization graduate age 25, married, completing 3-year tour in Air Force, desires position with private industry in western states. Experience includes logging, surveying, fire suppression, photogrammetry. Available in mid-September. (July)

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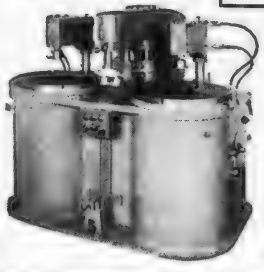

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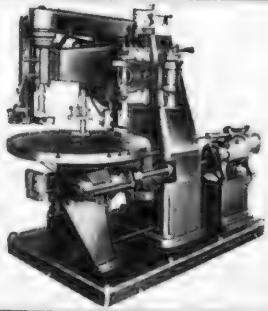

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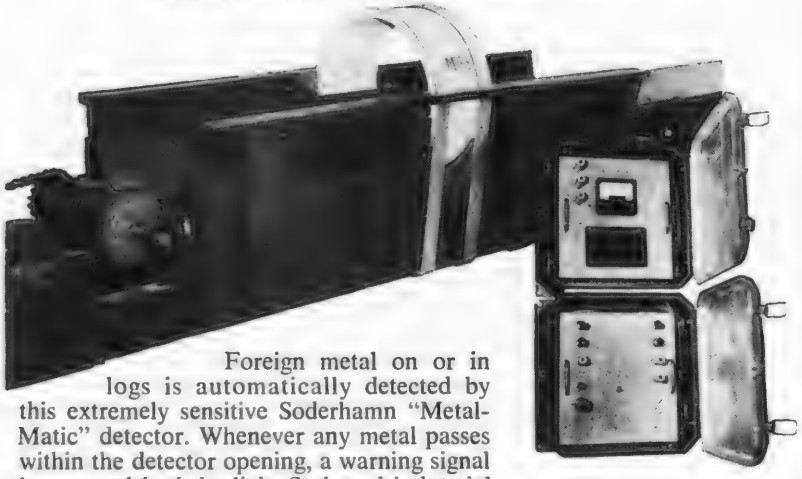

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FPRS Forest Products Journal

Vol. VII, No. 6
June, 1957

# How Long Will It Last—A Study of Glue Line Durability[1]

C. C. BOOTH and J. W. MAXWELL
Chemical Division, The Borden Co., New York, N. Y.

**Summarizes extensive tests conducted over a number of years by an adhesive manufacturer on the durability of various types of wood glues. The superiority of phenol- and resorcinol-formaldehyde resins is clearly established for severe service conditions. Reasonably long endurance can be expected with urea-formaldehyde resins when not subjected to direct exposure to the elements.**

## Introduction

WHEN SYNTHETIC RESIN ADHESIVES were introduced to the wood-using industry before World War II, little information was available regarding the life expectancy of glue lines under varying conditions of exposure and use. As experience was gained, it became obvious that certain types of resins were quite durable whereas other adhesives deteriorated rapidly through direct exposure to the elements.

The researcher and the adhesive manufacturer, however, could not afford to wait the indefinite time required by actual tests to determine the merits of adhesives being evaluated. As a result, accelerated tests were devised which made it possible to classify an adhesive as durable or nondurable, but because of insufficient actual outdoor exposure data for correlation, these accelerated tests were not useful as a guide for predicting longevity.

Considerable work has been done, particularly by the U. S. Forest Products Laboratory, Madison, Wis. on the durability of wood glues, [2, 3] and many excellent reports have been issued on the subject. The Borden Company's Chemical Division, a pioneer in manufacturing synthetic resin adhesives in the United States, recognized at the outset the need for obtaining factual information on glue joints to supplement data obtained from accelerated tests. A series of outdoor exposure tests was begun in 1939, for example, to examine several of the more prominent adhesives of that era. Unfortunately, these test panels were destroyed in a disastrous fire early in 1944. However, the merit of such a program had been established during this period. Another test series was started immediately.

This series included two types of weathering—*unprotected* and *protected*. The unprotected tests exposed to the elements various panels bonded with phenolic, resorcinol, and urea-formaldehyde resins. Varying veneer thicknesses and species of woods were used. The protected series consisted of panels that were stored in a shed away from direct exposure to sun, rain, and snow. They were, however, subjected to the normal outdoor temperatures and humidity prevailing throughout the year. This group was bonded with urea-formaldehyde adhesive mixes only.

About this time another concept of evaluation was introduced. This involved the use of controlled test conditions which closely paralleled the actual end use conditions to which many adhesives are subjected. These tests probably were less severe than present day accelerated tests such as those included in CS 35–56 or CS 45–55 Specifications, but not as time-consuming as long-range exposure tests. Several of these tests have considerable merit,[4] one of the most effective being the high temperature-moderate humidity test. This test is a valuable tool, particularly for determining heat resistance of adhesives.

It is intended that this paper shall present data obtained over a period of years by a manufacturer of wood adhesives. And, although it may overlap somewhat with previous tests conducted elsewhere, it is hoped that it presents several interesting approaches to the problem of durability.

## UNPROTECTED EXPOSURE TESTS

### Procedure

Several types of phenolic-, resorcinol- and urea-formaldehyde resin adhesives were evaluated as follows:

**Phenol-Formaldehyde Resins:** Both a liquid and spray-dried powder form of phenol-formaldehyde resin were studied. The syrup was a high alkali, 40 per cent solids resin formulated especially for bonding Douglas-fir. The spray-dried powder was formulated principally for use on Eastern hardwoods and was employed both unextended and extended with 50 and 100 parts of wheat flour. These adhesives required heat to effect optimum cure or polymerization.

**Resorcinol-Formaldehyde Resins:** Two types of resorcinol resins were evaluated—a straight resorcinol and a phenol-resorcinol modification. Several straight or unmodified resorcinol mixes employing different amounts of filler were used on various panel constructions. All bonding was done at room temperature (75° F.) conditions. The research work included one phenol-resorcinol formulation cured at an intermediate temperature of 140° F.

**Fortified Urea-Formaldehyde Resins:** One component and two component resin systems were evaluated. The one component resin was formulated by reacting the urea-formaldehyde constituent and a phenolic fortifying ingredient during the manufac-

[1] Presented at Session VI, Glues and Gluing, FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

[2] Selbo, M. L. 1949. Durability of woodworking glues for dwellings. FPRS Proc.: 361–

[3] Wangaard, F. F. 1954. Summary of information on durability of water-resistant woodworking glues. U. S. Forest Products Laboratory Report No. 1530 (revised).

[4] Blomquist, R. F. 1954. Evaluation of glues and glued products. Jour. FPRS IV (5):290–299.

*The Authors:* C. C. Booth received B. S. and M. degrees from State University of New York College of Forestry, Syracuse. He was employed by Monsanto Chemical Co. and in the home construction field before joining Borden Co. where he is now Head, Structural Adhesives Section, Sales Development Lab., Chemical Div., Bainbridge, N. Y.

J. W. Maxwell holds B. S. and M. S. degrees from the New York forestry college. Formerly associated with American Cyanamid Co. and Masonite Corp., he is now Technical Service Manager of the Borden Co. Chemical Div.

Table 1.—PHENOL-FORMALDEHYDE RESIN ADHESIVES—ORIGINAL QUALITY SHEAR AND EXPOSURE DURABILITY

| Mix | Type of Adhesive | Curing Conditions | Species | Construction | Original Quality Shear* Dry‡ | Wet§ | $3\frac{1}{2}$ Cycle | Exposure Period, Years† $\frac{1}{2}$ | 1 | $1\frac{1}{2}$ | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Liquid phenol+10 parts Filler§§ | Hot Pressed** | Yellow Birch | 3-ply 3/16" | 440–75 | 320–40 | 285–55 | 2 | 2 | 2 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 10 |
| | | | | 5-ply 5/8" | 300 0 | 95– 0 | 0–0 | 15 | 20 | 25 | 25 | 30 | 30 | 35 | 35 | 40 | 40 | 45 | 45 | 45 |
| B | +15 parts Filler | Hot Pressed | Yellow Poplar | 3-ply 3/16" | 425–95 | 280–75 | 240–90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 485–75 | 350– 5 | 260– 0 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 15 | 15 | 15 |
| C | +15 parts Filler | Hot Pressed | Red Gum | 3-ply 3/16" | 380–45 | 265–45 | 285–95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 600–85 | 460–75 | 470–90 | 2 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 15 | 15 | 15 | 15 | 15 |
| D | +15 parts Filler | Hot Pressed | Douglas-fir | 3-ply 3/10" | 380–90 | 295–15 | 295–65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| | | | | 5-ply 5/8" | 260–100 | 185–70 | 170–85 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 |
| E | Powdered phenol—unextended | Hot Pressed | Yellow Birch | 3-ply 3/16" | 590–75 | 530–60 | 490–95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 455–75 | 320–95 | 455–85 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | 5 |
| | | | Yellow Poplar | 3-ply 3/16" | 385–95 | 280–100 | 320–95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 370–95 | 405–85 | 335–90 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Sweet Gum | 3-ply 3/16" | 420–95 | 375–95 | 380–95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 345–50 | 325–70 | 315–50 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Douglas-fir | 3-ply 3/10" | 305–95 | 275–65 | 240–90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 305–100 | 265–85 | 270–95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| F | Powdered phenol+50 parts Extender†† | Hot Pressed | Yellow Birch | 3-ply 3/16" | 405–45 | 250 5 | 215–25 | 0 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | | |
| | | | Yellow Poplar | 3-ply 3/16" | 440–95 | 220– 0 | 210– 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| G | Powdered phenol+100 parts Extender | Hot Pressed | Yellow Birch | 3-ply 3/16" | 390–90 | 285–10 | 370–30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | | | Yellow Poplar | 3-ply 3/16" | 420–95 | 350– 0 | 340–15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | | |

*The first value is the average joint strength in pounds per square inch; the second value is the average estimated per cent wood failure. Each value is the average of 5 specimens.
†The figure represents per cent delamination of total glue line area.
‡Tested dry.
§Tested wet after 48 hours of soaking at room temperature.
Tested wet after 3 cycles of soaking 16 hours at room temperature and drying 8 hours at 145° F. ± 5° F., followed by an additional 16 hours of soaking at room temperature.
§§Walnut shell flour—300 mesh.
**Curing temperature 280° F.
††Wheat flour extender.

turing process of the basic resin. The principal advantage of this resin is its ability to give mild boil-proof bonds when cured at room temperature. For this study, both room temperature and elevated temperature curing conditions were employed. The two-component resin utilized resorcinol as the fortifying ingredient. It was incorporated into the urea resin at the time of mixing with catalyst. Curing conditions of mild heat (100° F.) were employed with this formulation.

**Urea-Formaldehyde Resins:** Both a liquid and a spray-dried powder were used. Panels bonded with the liquid resin were cured at room temperature (75° F.) and elevated temperature (240° F.). A typical cold and hot-press catalyst, were admixed with the resins. The powder resin had its filler and catalyst incorporated and required only mixing with water before using. This adhesive was cured at room temperature conditions.

**General:** In most instances, three-ply 3/16-inch panels and five-ply 5/8-inch panels composed of yellow birch, sweet gum, yellow poplar, and Douglas-fir veneers were bonded with the various adhesive mixes. The stock was conditioned to approximately 8 per cent equilibrium moisture content before gluing. Generally, one 16- x 16-inch panel of every species was prepared with each adhesive mix using a conventional spread.

After an initial aging period of at least seven days at 75° F. and 58 per cent relative humidity, the constructions were trimmed to 15 x 15 inches. A 3¼-inch strip then was removed from one edge and cut into standard plywood tensile shear specimen for testing dry, testing wet after 48 hours' soaking at room temperature, and wet after 3½ cycles composed of 16 hours' soaking at room temperature and eight hours' soaking at 145° F. These data represented original glue-line quality.

The remainder of the panel was mounted on the outdoor exposure rack (Fig. 1). Observations were made at six months intervals for the first two years and annually thereafter. Failure was recorded as per cent delamination of total glue area. Pertinent test data are contained in Tables 1, 2, and 3.

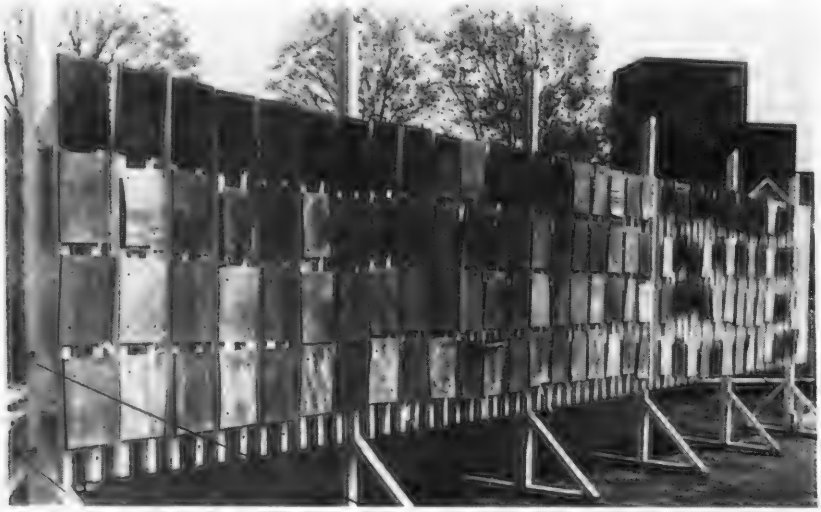

Fig. 1.—Exposure fence at the Bainbridge (New York) Development Laboratory of the Borden Company's Chemical Division.

## Discussion and Results

**Phenol-Formaldehyde Resins:** The high-caustic containing liquid phenolic apparently does an outstanding job on Douglas-fir (Table 1). Original quality shear is good and, after 11 years on the exposure fence, delamination is negligible. There is substantial evidence that springwood areas of the faces are weathering poorly, in contrast to the denser summerwood. Adhesion at the glue lines remains excellent. Performance on low and medium density hardwood, as exhibited by poplar and gum, is good. There is some pronounced delamination in the thicker constructions of five-ply 5/8-inch veneers, presumably from the greater stresses set up within these panels, in contrast to the three-ply 3/16-inch veneers. Moderate to severe delamination is apparent in high density species (birch). Again, the greatest failure occurs in the thicker panels. This particular phenol adhesive does not appear suitable for bonding high-density Eastern hardwoods.

The spray-dried phenol was evaluated on yellow birch and yellow poplar

lar three-ply 3/16-inch panels only (Table 1). Although original shear quality decreases as flour extension is increased, the fence tests do not show as great reduction in glue-line quality. There are some indications, after 11 years' exposure, that borderline durability performance can be expected with phenol resins highly extended with wheat flour.

**Resorcinol-Formaldehyde Resins:** The various straight resorcinol mixes are tabulated in Table 2. There does not appear to be any significant difference in performance with respect to the species of wood used or to the moderate extensions of nut shell flour. There is some evidence again, however, that delamination is somewhat greater on the thicker five-ply 5/8-inch constructions. In general, it appears that, although durability performance can be rated high, it is nevertheless somewhat erratic.

The phenol-resorcinol shows outstanding resistance to weathering after 11 years' exposure and is somewhat superior to the unmodified resorcinol in this respect. This may be due in part to the intermediate temperature curing conditions employed.

**Fortified Urea-Formaldehyde Resins:** The results of the various fortified urea combinations are compared with the unmodified urea resins in Table 3. It is apparent that the moderate fortification employed considerably enhances durability properties of the urea-formaldehyde bond. Although performance falls short of the phenol or resorcinol resins studied, there is evidence that equal performance may

**Table 2.—RESORCINOL-FORMALDEHYDE RESIN ADHESIVES—ORIGINAL QUALITY SHEAR AND EXPOSURE DURABILITY**

| Mix | Type of Adhesive | Curing Conditions | Species | Construction | Original Quality Shear* Dry‡ | Wet§ | 3½ Cycle | Exposure Period, Years† ½ | 1 | 1½ | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Straight Resorcinol | Cold Pressed§§ | Yellow Birch | 3-ply 3/16" | 585- 90 | 660- 85 | 625-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | F | F |
| | | | | 5-ply 5/8" | 465- 95 | 455- 70 | 450- 95 | 2 | 5 | 5 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| | | | Yellow Poplar | 3-ply 3/16" | 315 100 | 300- 95 | 310 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 430-100 | 325- 95 | 320- 95 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Red Gum | 3-ply 3/16" | 460-100 | 460- 95 | 435- 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 400-100 | 380- 95 | 310- 95 | 0 | 2 | 2 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 10 | 10 |
| | | | Douglas-fir | 3-ply 3/10" | 265- 95 | 230- 95 | 220-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | |
| | | | | 5-ply 5/8" | 245- 60 | 215- 60 | 205- 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| B | Straight Resorcinol+20 parts Filler** | Cold Pressed | Yellow Birch | 3-ply 3/16" | 635 85 | 465 70 | 450 85 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | | 5-ply 5/8" | 520 55 | 645 90 | 540 100 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | |
| | | | Yellow Poplar | 3-ply 3/16" | 395-100 | 280- 95 | 300-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 265-100 | 250- 95 | 255-100 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Red Gum | 3-ply 3/16" | 290- 85 | 260 75 | 250 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 |
| | | | | 5-ply 5/8" | 415- 95 | 415- 85 | 425-100 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Douglas-fir | 3-ply 3/10" | 240- 60 | 210- 70 | 130- 50 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 15 | 15 |
| | | | | 5-ply 5/8" | 180- 25 | 190- 5 | 220- 30 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| C | Straight Resorcinol+40 parts Filler | Cold Pressed | Yellow Birch | 3-ply 3/16" | 350- 0 | 265- 10 | 295- 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | | Yellow Poplar | 3-ply 3/16" | 255- 80 | 265- 95 | 225- 80 | 0 | 0 | 0 | 2 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| | | | | 5-ply 5/8" | 245 60 | 280 50 | 255 75 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 | 5 | |
| | | | Red Gum | 3-ply 3/16" | 320- 85 | 295- 80 | 280- 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Douglas-fir | 3-ply 3/10" | 220 65 | 170 45 | 185 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 230- 45 | 200- 20 | 195- 25 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 5 | 5 |
| D | Phenol-Resorcinol | Intermediate Temp.†† | Yellow Birch | 3-ply 3/16" | 465- 50 | 385- 65 | 370- 85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 385 80 | 430 15 | 415 70 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Yellow Poplar | 3-ply 3/16" | 330 85 | 310 75 | 325 100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 310- 80 | 250- 55 | 280- 90 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| | | | Red Gum | 3-ply 3/16" | 290- 95 | 400- 95 | 365-100 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 355 95 | 410 95 | 360 85 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | Douglas-fir | 3-ply 3/10" | 270- 90 | 260- 90 | 215- 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | 5-ply 5/8" | 285 95 | 295 90 | 320 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

*The first value is the average joint strength in pounds per square inch; the second value is the average estimated per cent wood failure. Each value is the average of 5 specimens.
†The figure represents per cent delamination of total glue line area.
‡Tested dry.
§Tested wet after 48 hours of soaking at room temperature.
Tested wet after 3 cycles of soaking 16 hours at room temperature and drying 8 hours at 145° F.±5° F., followed by an additional 16 hours of soaking at room temperature.
§§Curing temperature of 75° F.
**Walnut shell flour—300 mesh.
††Curing temperature of 140° F.

**Table 3.—UREA-FORMALDEHYDE RESIN ADHESIVES—ORIGINAL QUALITY SHEAR AND EXPOSURE DURABILITY**

| Mix | Type of Adhesive | Curing Conditions | Species | Construction | Original Quality Shear* Dry‡ | Wet§ | 3½ Cycle | Exposure Period, Years† ½ | 1 | 1½ | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Liquid Urea—unextended | Cold Pressed§§ | Yellow Birch | 3-ply 3/16" | 470- 50 | 430- 50 | 235- 5 | 2 | 20 | 50 | 100 | .. | .. | .. | .. | .. | .. | .. | .. | . |
| | | | | 5-ply 5/8" | 385- 10 | 370- 5 | 140 0 | 0 | 10 | 20 | 25 | 50 | 75 | | | | | | | |
| | | | Yellow Poplar | 3-ply 3/16" | 290-100 | 255- 95 | 155- 0 | 0 | 2 | 10 | 20 | 40 | 75 | | | | | | | |
| | | | | 5-ply 5/8" | 310-100 | 300- 75 | 165- 85 | 0 | 2 | 5 | 10 | 40 | 60 | .. | .. | .. | .. | . | | |
| | | | Red Gum | 3-ply 3/16" | 315- 95 | 270- 85 | 150- 35 | 0 | 15 | 40 | 80 | 100 | .. | .. | .. | .. | | | | |
| | | | | 5-ply 5/8" | 455- 80 | 440- 80 | 150- 0 | 0 | 2 | 20 | 35 | 70 | 80 | .. | .. | . | . | .. | .. | .. |
| | | | Douglas-fir | 3-ply 3/10" | 270-100 | 175- 15 | 0- 0 | 2 | 20 | 65 | 100 | .. | .. | . | . | . | . | .. | .. | .. |
| | | | | 5-ply 5/8" | 280-100 | 170- 5 | 0- 0 | 0 | 2 | 10 | 20 | 40 | 70 | | | | | | | |
| B | Powder Urea—unextended | Cold Pressed | Yellow Birch | 3-ply 3/16" | 450- 25 | 375- 60 | 345- 40 | 2 | 15 | 50 | 95 | 100 | .. | .. | .. | .. | .. | .. | .. | .. |
| | | | | 5-ply 5/8" | 480 15 | 435- 40 | 385 0 | 0 | 15 | 35 | 60 | 70 | 75 | | | | | | | |
| | | | Yellow Poplar | 3-ply 3/16" | 335-100 | 280-100 | 225- 85 | 0 | 5 | 20 | 50 | 65 | 95 | .. | .. | .. | .. | .. | .. | .. |
| | | | | 5-ply 5/8" | 285-100 | 285-100 | 245- 25 | 0 | 2 | 10 | 20 | 40 | 50 | .. | .. | .. | .. | .. | .. | .. |
| | | | Red Gum | 3-ply 3/16" | 465- 95 | 360- 20 | 285- 35 | 0 | 5 | 45 | 85 | 100 | | | | | | | | |
| | | | | 5-ply 5/8" | 375- 95 | 280- 15 | 245- 80 | 0 | 2 | 20 | 35 | 50 | 70 | .. | .. | .. | .. | .. | .. | .. |
| | | | Douglas-fir | 3-ply 3/10" | 255- 65 | 210- 20 | 135- 5 | 2 | 10 | 60 | 90 | 90 | 100 | | | | | | | |
| | | | | 5-ply 5/8" | 205- 20 | 170- 0 | 60- 0 | 0 | 10 | 30 | 75 | 85 | 90 | .. | .. | | | | | |
| C | Liquid Urea+10 parts Resorcinol | Mild Heat** Intermediate Temp.†† | Yellow Birch | 3-ply 3/16" | 565- 30 | 480- 20 | 460- 10 | 0 | 0 | 0 | 0 | 0 | 5 | 15 | 35 | 65 | .. | .. | .. | .. |
| | | | Yellow Birch | 3-ply 3/16" | 525- 50 | 475- 75 | 485- 80 | 0 | 0 | 0 | 0 | 0 | 5 | 30 | 70 | 95 | .. | .. | .. | |
| D | Liquid Urea+13 parts Resorcinol | Mild Heat Intermediate Temp. | Yellow Birch | 3-ply 3/16" | 520- 55 | 510- 75 | 520- 70 | 0 | 0 | 0 | 0 | 2 | 5 | 20 | 40 | 65 | .. | .. | | .. |
| | | | Yellow Birch | 3-ply 3/16" | 555- 60 | 550-100 | 550-100 | 0 | 0 | 0 | 0 | 2 | 5 | 10 | 20 | 35 | | | . | . |
| E | Liquid Urea—Internally Fortified | Cold Pressed | Yellow Birch | 3-ply 3/16" | 505- 75 | 450- 80 | 400- 20 | 0 | 0 | 0 | 0 | 2 | 5 | 15 | 35 | | | | . | .. |
| | | Hot Pressed‡‡ | Yellow Birch | 3-ply 3/16" | 560- 65 | 485- 90 | 445- 35 | 0 | 0 | 0 | 2 | 20 | 50 | 80 | 100 | | | | . | . |

The first value is the average joint strength in pounds per square inch; the second value is the average estimated per cent wood failure. Each value is the average of 5 specimens.
The figure represents per cent delamination of total glue line area.
Tested dry.
Tested wet after 48 hours of soaking at room temperature.
ed wet after 3 cycles of soaking 16 hours at room temperature and drying 8 hours at 145° F.±5° F., followed by an additional 16 hours of soaking at room temperature.
uring temperature of 75° F.
ured 8 hours at 100° F.
ured 4 hours at 140° F.
ring temperature of 240° F.

be obtained at a higher level of fortification.[5]

In the case of the resorcinol fortified mixtures (Mixes C and D, Table 3), a higher curing temperature seems to enhance bond quality. Conversely, the use of hot press curing conditions in bonding appears to impair the adhesive characteristics of the internally fortified urea resin (Mix E, Table 3).

Panels bonded with the straight urea adhesives failed quickly on the fence, revealing the non-durable characteristics of this type of adhesive. There appears to be no significant difference in this respect between the room temperature setting liquid and powder resins employed in this study.

[5] Blomquist, R. F. and W. Z. Olson. 1955. Durability of fortified urea-resin glues in plywood joints. For. Prod. Jour. V (1): 50–56.

## Summary and Conclusion

**Phenol-Formaldehyde Resins:** There is now convincing evidence that the liquid phenolic used herein has a particular affinity for Douglas-fir, exhibiting excellent durability thereon.

Table 4.—ENDURANCE OR UREA RESIN UNDER CONDITIONS OF PROTECTED OUTDOOR EXPOSURE*

| Mix | Type of Adhesive | Parts Extension per 100 Parts Resin by Weight‡ | Curing Conditions | Original Quality Shear Dry§ | Original Quality Shear Wet‖ | Endurance—Years† 7½ Dry | 7½ Wet | 10 Dry | 10 Wet | 11 Dry | 11 Wet |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Liquid Urea—Separate Application¶ | None | Cold Pressed** | 495–85 | 490–85 | 325–35 | 325–40 | 325–25 | 275–60 | | |
| | | 50 Parts | | 495–65 | 420–35 | 330–20 | 290–15 | 330–10 | 180–0 | | |
| | | 100 Parts | | 465–55 | 380–5 | 335–15 | 240–5 | 335–15 | 195–0 | | |
| B | Liquid Urea—Catalyst Admixed†† | None | Cold Pressed | 500–35 | 495–30 | 450–0 | 420–20 | 440–15 | 400–20 | | |
| | | 50 Parts | | 440–25 | 375–15 | 370–0 | 340–0 | 370–10 | 325–10 | | |
| | | 100 Parts | | 425–20 | 320–5 | 295–0 | 175–0 | 165–10 | 60–0 | | |
| C | Liquid Urea—Conventional Catalyst‡‡ | None | Hot Pressed§§ | 620–100 | 480–85 | 485–85 | 480–80 | 485–75 | 445–90 | | |
| | | 50 Parts | | 570–60 | 450–55 | 445–30 | 430–15 | 445–45 | 400–35 | | |
| | | 100 Parts | | 460–45 | 375–25 | 390–10 | 370–15 | 390–30 | 305–25 | | |
| D | Liquid Urea—Fortified‖‖ | None | Hot Pressed | 580–80 | 460–100 | 550–90 | 445–100 | 520–75 | 415–90 | 460–70 | 15–80 |
| | | 50 Parts | | 500–60 | 295–15 | 500–35 | 270–0 | | | | |

*The panels were stored in a shed at Bainbridge, N. Y. where they were subjected to prevailing temperature and relative humidity conditions, but protected from direct exposure to sun, rain, and snow.
†The first value is the average joint strength in pounds per square inch; the second value is the average estimated per cent wood failure. Each value is the average for 15 specimens.
‡Wheat flour extender.
§Tested dry.
‖Tested wet after 48 hours of soaking at room temperature.
¶A reactive catalyst was spread on one gluing surface and the uncatalyzed resin on the opposite surface to be bonded.
**Curing temperature of 75° F.
††The catalyst added to the resin before using as an adhesive mix.
‡‡The catalyst, formulated for hot pressing applications, was incorporated with the resin before use.
§§Curing temperature of 240° F.
‖‖The mix fortified with 8 parts resorcinol per 100 parts resin.

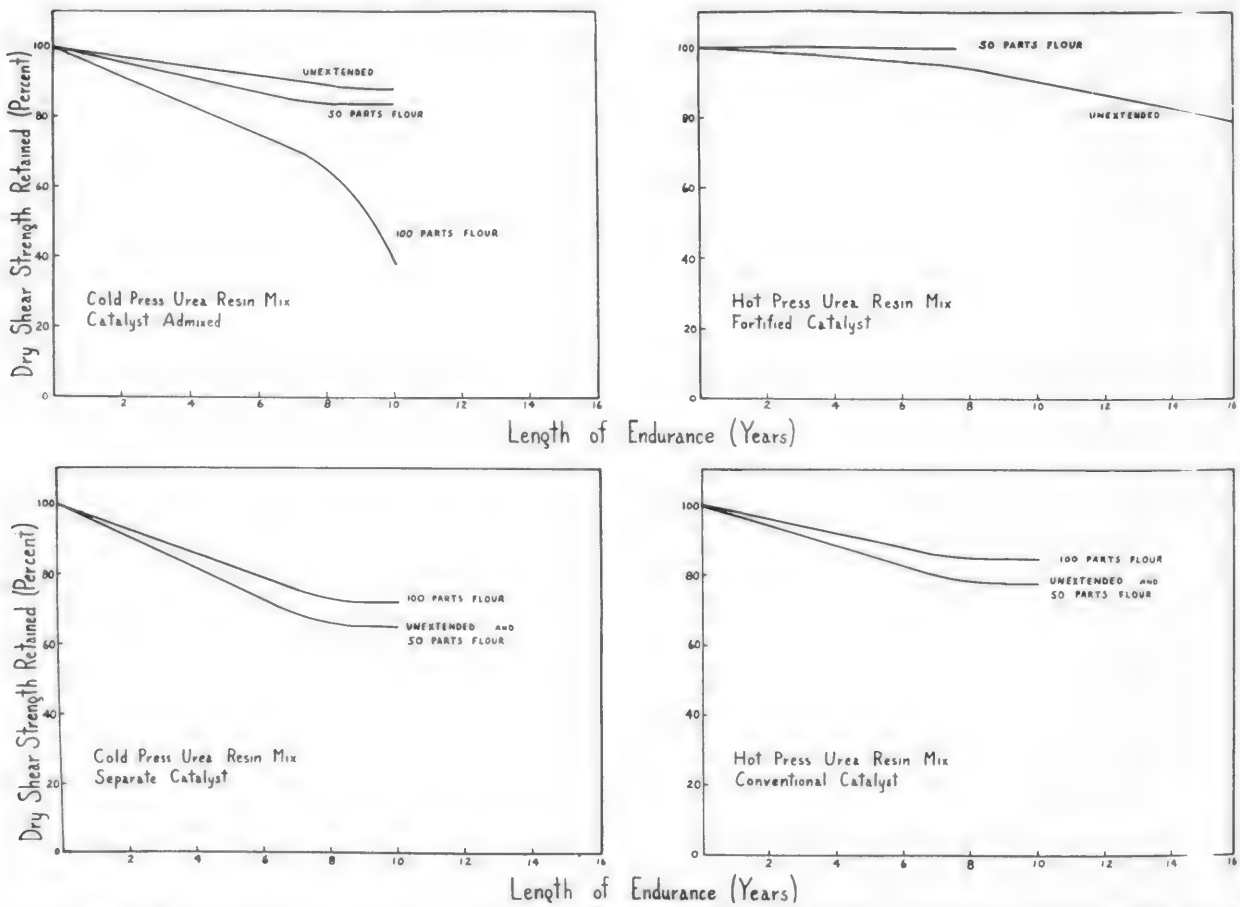


Fig. 2.—Effect of protected exposure on the dry shear strength of yellow birch panels bonded with various urea-formaldehyde adhesive mixes unextended and extended with 50 and 100 parts wheat flour.

Performance on Eastern hardwoods is erratic, with spotty results evident with medium and low-density species (red gum and yellow poplar) and generally poor durability evident on dense species (yellow birch).

The spray-dried phenol continues to exhibit excellent adhesion, with little distinction noted between the unextended and extended mixes.

**Resorcinol-Formaldehyde Resins:** The straight resorcinol product continues to exhibit excellent durability after 11 years' aging, although some signs of questionable durability are evident. There is some evidence that thicker constructions of high density species, i.e. five-ply 5/8-inch birch, deteriorate more readily than thin construction, i.e. three-ply 3/16-inch birch. This probably is caused by greater stresses set up within the panel. This condition does not appear to be evident in medium (red gum) and low density (yellow poplar) species.

Certain isolated incidents of failure, namely, red gum and Douglas-fir bonded at room temperature with mild nut shell flour extension, may be significant. These spotty failures tend to indicate that room-temperature curing results in erratic durability performance, and that some heat might be advantageous for optimum performance. The phenol-resorcinol adhesive continues to exhibit outstanding durability after 11 years' aging regardless of constructions employed. This is noteworthy since the curing temperature was only 140° F.

**Fortified Urea-Formaldehyde Resins:** It is evident that urea resins will last only a comparatively brief time—two to four years in this study. However, if fortified, the durability properties can be improved, the degree of durability being dependent on the type and amount of fortifying ingredient used.

## PROTECTED EXPOSURE TESTS

### Procedure

Four types of urea-formaldehyde adhesive mixes were studied, two cold-press and two hot-press formulations. Each type of mix was employed unextended and extended with 50 parts and 100 parts of wheat flour.

**Cold-Press Urea Resin (Room Temperature Cure:** The cold-press mixtures were used with a separate application type catalyst and an admixed catalyst. The separate application technique involved spreading the resin on one gluing surface and the catalyst solution on the opposite surface to be glued, then mating the two components and subjecting them to pressure. The admixed catalyst was incorporated with the resin before spreading the surfaces to be glued.

**Hot-Press Urea Resin (Elevated Temperature Cure):** The hot press formulations included a conventional admixed catalyst and a fortified catalyst. In both cases the catalyst was mixed with resin before using. The latter mix contained resorcinol as the fortifying ingredient.

**General:** Three 14- x 14-inch three-ply 3/16-inch yellow birch panels were bonded with each adhesive mix. The veneers were conditioned to 8 per cent equilibrium moisture content before use. At the specified test interval, a 3-inch strip was removed from one edge of the panels, allowing for an approximate 1-inch trim for the initial test, and cut into 10 standard plywood shear specimens. Odd-numbered specimens were tested in dry shear and even-numbered speci-

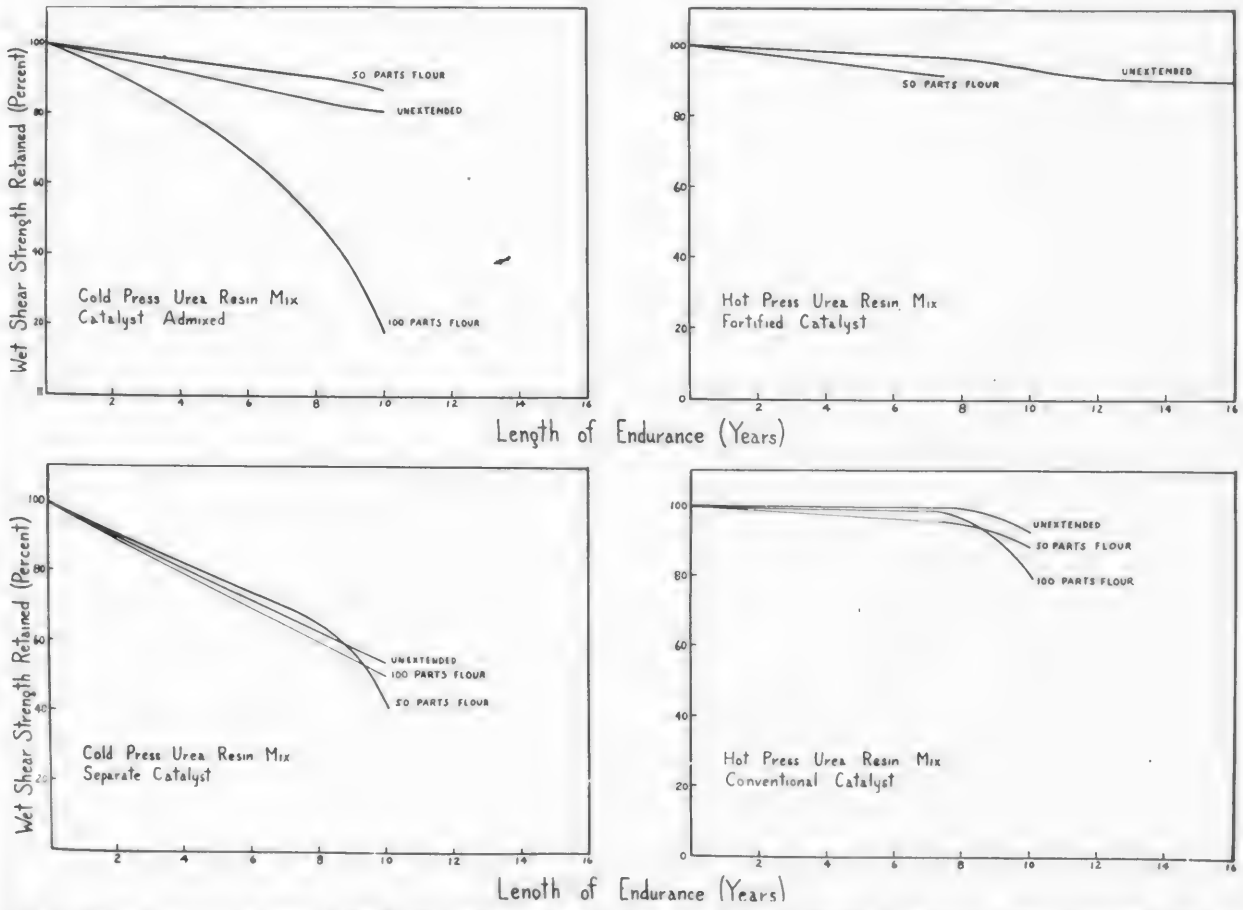


Fig. 3.—Effect of protected exposure on the wet shear strength of yellow birch panels bonded with various urea-formaldehyde adhesive mixes unextended and extended with 50 and 100 parts wheat flour.

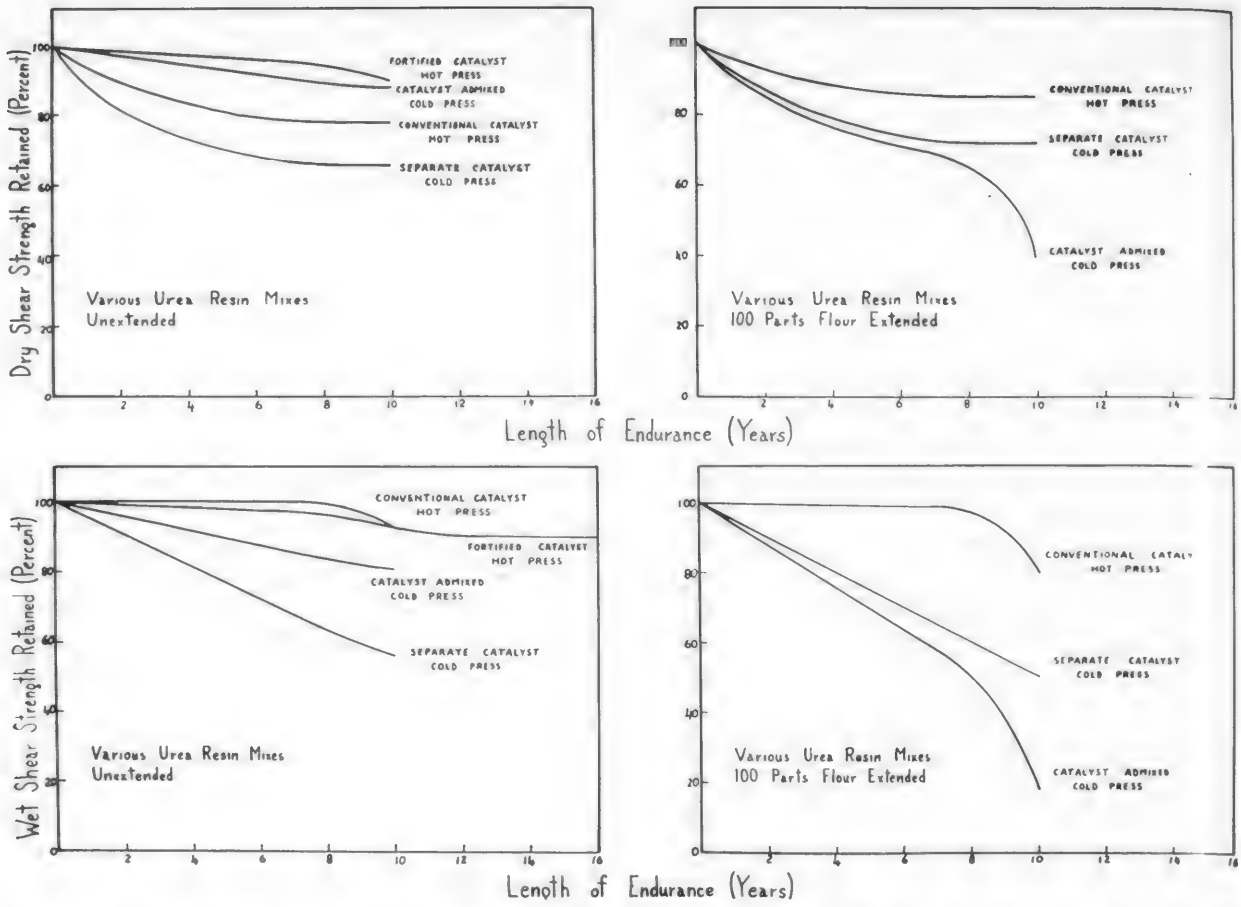
Dry Shear Strength Retained (Percent)
FORTIFIED CATALYST HOT PRESS
CATALYST ADMIXED COLD PRESS
CONVENTIONAL CATALYST HOT PRESS
SEPARATE CATALYST COLD PRESS
Various Urea Resin Mixes Unextended
Various Urea Resin Mixes 100 Parts Flour Extended
Length of Endurance (Years)
Wet Shear Strength Retained (Percent)
CONVENTIONAL CATALYST HOT PRESS
FORTIFIED CATALYST HOT PRESS
CATALYST ADMIXED COLD PRESS
SEPARATE CATALYST COLD PRESS
Various Urea Resin Mixes Unextended
Various Urea Resin Mixes 100 Parts Flour Extended
Length of Endurance (Years)

**Fig. 4.—Comparative picture of the shear strength retention of yellow birch constructions bonded with several urea-formaldehyde resin mixtures unextended and extended with 100 parts wheat flour, subjected to protected exposure conditions.**

mens tested in wet shear, after 48 hours' soaking at room temperature, giving a total number of 15 specimens for the three panels involved in each test condition.

Test intervals were selected arbitrarily as immediate, 7½ and 10 years. The immediate test allowed for a panel maturing period of at least seven days at 75° F. and 58 per cent relative humidity. After the immediate test, panel segments were stored in an unheated shed exposed to outdoor temperature and humidity conditions, but protected from direct exposure to sun, rain, snow, and wind. It is estimated that temperatures ranged from −20° F. to 100° F., and relative humidity from 20 to 85 per cent during this period. Test data are tabulated in Table 4.

### Discussion and Results

**Urea Resin Cured at Room Temperature (75° F.) and Elevated Temperatures (240° F.):** The test data for the various adhesive mixtures subjected to protected exposure are cited in Table 4. In general, the hot press formulations appear to exhibit superior bond strength to the cold press mixtures after 10 years' aging. This factor is illustrated more emphatically in Figs. 2, 3, and 4.

In Fig. 2, dry strength retention over a 10-year period is shown for each type of urea-formaldehyde mix employed at different levels of flour extension except for the unextended fortified formulation (Mix D, Table 4) which covers a 16-year period. Fig 3 shows wet-strength retention for the same mixtures, and it should be noted in the case of the room temperature curing mixes that reduction in strength is quite severe. Fig. 4 contains a composite of dry and wet-strength retention for all mixes unextended and 100 parts wheat flour extended. It is apparent, particularly at high wheat extensions, that the unfortified hot press formulation continues to exhibit a high level of performance after 10 years' endurance. Unfortunately, a highly extended fortified mix was not included in the study for comparison.

Another interesting factor illustrated in Fig. 4 concerns the behavior of the separate application catalyst mix. In the case of the unextended mix, both dry and wet-strength retention were the lowest of the four formulations investigated. However, when employed in high wheat flour extended mixtures, the separate application type of catalyst mix improves in performance and is somewhat superior to the admixed cold press catalyst formulation.

### Summary and Conclusion

Urea-formaldehyde bonded panels can be expected to give reasonably long service when used in environments protected from direct exposure to the elements.

In general, hot -press urea-formaldehyde resin bonded panels will exhibit greater durability in protected exposure than will cold-press panels. This condition is thought to be a function of film pH since hot press mixes usually result in a less acidic glue line than do cold press mixes.

## CONTROLLED ACCELERATED TESTS

### High Temperature — Moderate Humidity

#### Procedure

Various urea,- fortified urea- and phenol-formaldehyde resin mixes were evaluated.

Table 5.—CONTINUOUS EXPOSURE AT 160° F. AND 60% RELATIVE HUMIDITY—3-PLY 3/16-INCH YELLOW BIRCH VENEERS*

| Mix | Type of Adhesive | Curing Conditions | Shear Test | Aging Period—Months† Original | 2 mos. | 4 mos. | 6 mos. | 8 mos. | 10 mos. | 12 mos. |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Liquid Urea—unextended | Cold Pressed‡ | Dry§ | 585-65 | 162-0 | 90-0 | TF | -- | - | ---- |
| | | | Wet¶ | 480-70 | 55-0 | TF | ---- | ------ | ---- | ---- |
| | | | 3½ Cycle** | 355-5 | TF | -- - | - | ------ | ---- | ---- |
| B | Liquid Urea+50 parts Extender †† | Hot Pressed†† | Dry | 530-50 | 170-0 | 70-0 | 10-0 | TF | - | |
| | | | Wet | 440-40 | 25-0 | TF | -- -- | | - | |
| C | Liquid Urea+100 parts Extender | Hot Pressed | Dry | 335-30 | 195-0 | 90-0 | 90-0 | TF | - | |
| | | | Wet | 280-20 | 10-0 | TF | | | | |
| D | Liquid Urea+150 parts Extender | Hot Pressed | Dry | 400-30 | 245-0 | 180-0 | 205-0 | 110-0 | 10-0 | TF |
| | | | Wet | 230-20 | 60-0 | TF | ------ | ------ | ------ | ------ |
| E | Urea Resin+13 parts Resorcinol | Mild Heat§§ | Dry | 480-40 | 235-0 | 185-0 | 110-0 | 95-0 | 80-0 | 65-0 |
| | | | Wet | 510-60 | 400-5 | 275-0 | 150-0 | 115-0 | 80-0 | 45-0 |
| | | | 3½ Cycle | 455-70 | 265-5 | 155-0 | 65-0 | 90-0 | 50-0 | TF |
| | | | Boil ¶¶ | 445-25 | 265-0 | 170-0 | 100-0 | 50-0 | 40-0 | 30-0 |
| F | Urea Resin+13 parts Resorcinol | Intermediate Temperature¶¶ | Dry | 495-80 | 215-0 | 175-0 | 120-0 | 125-0 | 75-0 | 55-0 |
| | | | Wet | 435-80 | 290-0 | 205-0 | 125-0 | 95-0 | 50-0 | 20-0 |
| | | | 3½ Cycle | 460-20 | 260-0 | 165-0 | 40-0 | 80-0 | 10-0 | TF |
| | | | Boil | 425-60 | 255-0 | 140-0 | 75-0 | 55-0 | 30-0 | 20-0 |
| G | Urea Resin+13 parts Resorcinol+25 parts Extender | Intermediate Temperature | Dry | 485-85 | 250-5 | 150-0 | 110-0 | 80-0 | 50-0 | 35-0 |
| | | | Wet | 430-70 | 260-0 | 175-0 | 105-0 | 60-0 | 40-0 | 20-0 |
| | | | 3½ Cycle | 420-40 | 220-10 | 150-0 | 55-0 | 65-0 | 20-0 | TF |
| | | | Boil | 325-10 | 110-0 | 20-0 | TF | ------ | ------ | ------ |
| H | Phenol+50 parts Extender | Hot Pressed*** | Dry | 450-50 | 430-50 | 400-40 | 370-40 | 330-30 | 330-30 | 310-30 |
| | | | Wet | 340-50 | 310-50 | 290-50 | 260-60 | 260-55 | 250-45 | 230-50 |
| | | | Boil | 320-20 | 300-15 | 280-15 | 245-10 | 215-5 | 190-5 | 185-5 |
| I | Phenol+100 parts Extender | Hot Pressed | Dry | 400-40 | 380-40 | 370-30 | 340-30 | 340-20 | 300-20 | 280-20 |
| | | | Wet | 300-30 | 280-30 | 265-20 | 240-20 | 230-15 | 225-15 | 210-15 |
| | | | Boil | 250-15 | 250-10 | 230-10 | 215-10 | 200-5 | 100-5 | 160-5 |
| J | Phenol+150 parts Extender | Hot Pressed | Dry | 370-40 | 350-40 | 340-30 | 330-30 | 280-35 | 270-30 | 215-20 |
| | | | Wet | 225-10 | 235-5 | 220-5 | 220-5 | 225-5 | 220-5 | 210-5 |
| | | | Boil | 200-10 | 200-10 | 190-5 | 195-5 | 175-5 | 170-5 | 155-5 |

*After gluing, panels were allowed to mature 10 days before preparing specimens. Original shear tests were then performed and remaining specimens conditioned for periods indicated. Ten days before each test period, the appropriate specimens were placed in an atmosphere of 75° F. and 62% relative humidity.

†The first value is the average joint strength in pounds per square inch; the second value is the average estimated per cent wood failure. Each value is the average of 5 specimens.

‡Curing temperature of 75° F.

§Specimens tested dry.

¶Total failure.

¶¶Specimens soaked 48 hours in water at 75° F. and tested wet.

**Specimens soaked 16 hours in water at 75° F. and then dried 8 hours at 145° F. This cycle repeated two more times followed by additional 16 hours' soaking at 75° F. Specimens tested wet.

††Curing temperature of 240° F.

¶¶Wheat flour extender.

§§Curing temperature of 100° F.

Specimens boiled 3 hours in water, cooled, and tested wet.

¶¶Curing temperature of 140° F.

***Curing temperature of 280° F.

**Urea-Formaldehyde Resins:** A cold-press unextended mix and several hot-press formulations extended with 50, 100, and 150 parts of wheat flour were studied. The cold-press formulation was cured at room temperature of 75° F., whereas the various hot-press formulations were cured at an elevated temperature of 240° F.

**Fortified-Urea Resins:** Three mixes moderately fortified with 13 parts of resorcinol were evaluated. One mixture was bonded under mild heat of 100° F. for several hours. Another formulation was cured at an intermediate temperature of 140° F. for a lesser number of hours. The third mixture involved the use of 13 parts resorcinol plus a mild wheat flour extension of 25 parts and cured under an intermediate temperature of 140° F.

**Phenol-Formaldehyde Resins:** Phenol resin mixes extended with 50,100, and 150 parts of wheat flour were evaluated in this study. These mixes were cured at an elevated temperature of 280° F.

**General:** Yellow birch three-ply 3/16-inch panels were bonded with the various mixtures involved using veneers conditioned to 8 per cent equilibrium moisture content. After the panels matured 10 days at 75° F. and 58 per cent relative humidity, they were cut into test specimens. Original shear tests were then performed, five specimens per test, and the remaining specimens were exposed continuously to an atmosphere of 160° F. and 60 per cent relative humidity, for the periods indicated in Table 5. Ten days before each test period, the appropriate specimens were placed in an atmosphere of 75° F. and 58 per cent relative humidity. The various tests employed are contained in Table 5.

## Discussion and Results

The high temperature-moderate humidity test gives an accurate picture of how an adhesive can be expected to perform with respect to durability and, to a large extent, heat resistance. It is obvious from Table 5 that a conventional urea-formaldehyde, unmodified, fails rapidly. It is interesting to note, however, that as the wheat flour extension is increased, dry strength durability also increases slightly. This phenomenon can be ascribed, perhaps, to the plasticizing effect of the flour and the lesser amount of resin solids available. This condition should not be interpreted to mean that flour extension will also enhance water resistance. Experience shows that the reverse is true, and that water resistance definitely will be impaired.

The addition of a small amount of resorcinol—in this case 13 per cent—to the urea resin substantially improves durability of the glue line. Although a higher level of resorcinol was not employed in this evaluation, because of a prohibitive wet glue line cost, Blomquist and Olson[6] indicate that durability can be augmented by increasing resorcinol content. The same degree of fortification also can be obtained by the use of melamine in proper proportions.

The wheat flour extended phenol resin formulations (Mixes H, I, and J, Table 5) show the excellent durability of this adhesive. Although flour extensions in field practice usually are not as high with a phenol as employed herein, it is interesting nevertheless, to note the negligible effect of extension on glue-line resistance to high temperature–moderate humidity conditions. Unfortunately, the tests were limited to 12 months' duration and, as a result, it was impossible to

[6] See footnote 5.

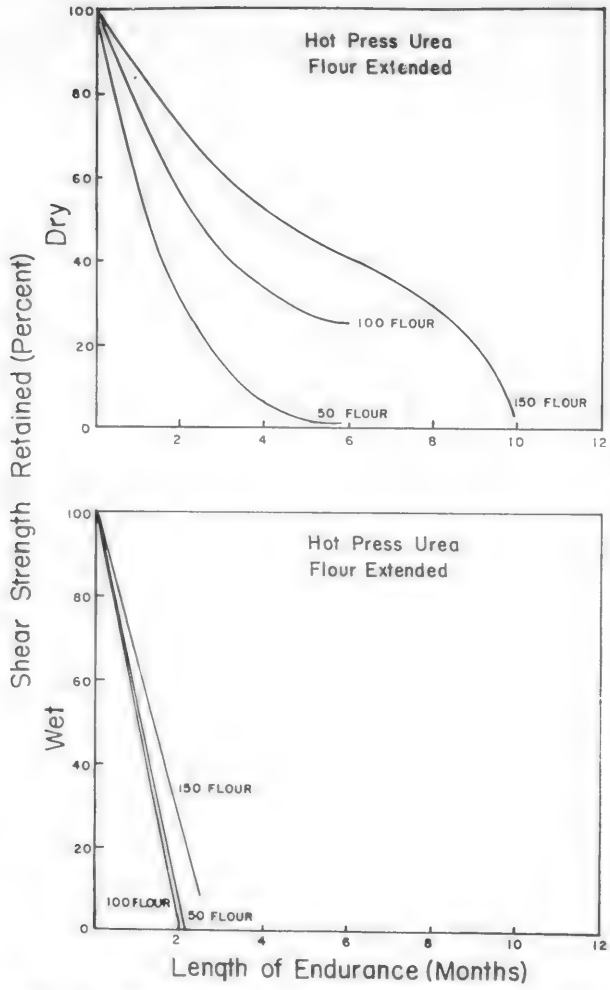


Fig. 5.—Effect of exposure of 160° F. and 60 per cent relative humidity on the shear strength of yellow birch panels bonded with urea-formaldehyde adhesive mixes.

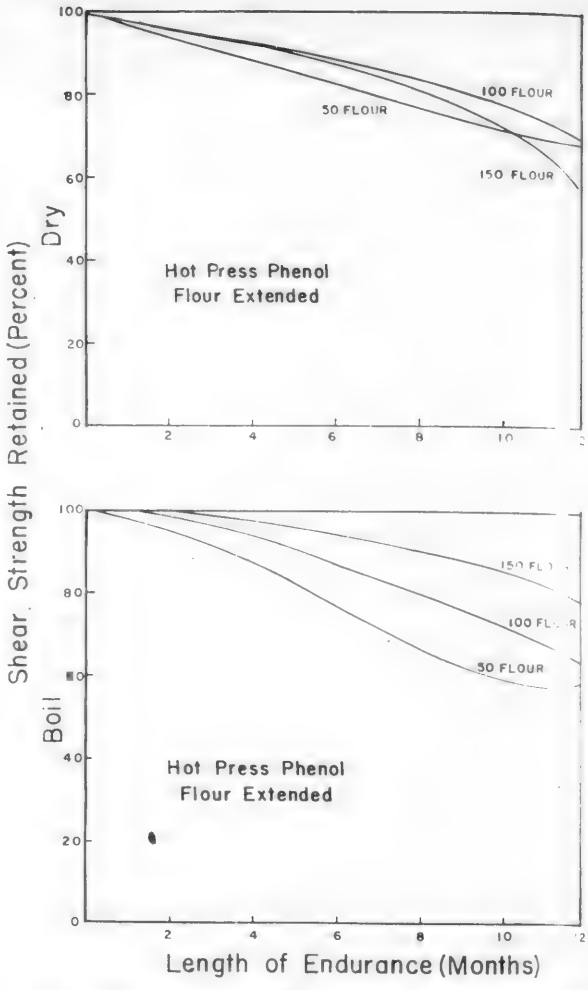


Fig. 6.—Effect of exposure to 160° F. and 60 per cent relative humidity on the shear strength of yellow birch panels bonded with phenol-foormaldehyde adhesive mixes.

determine the exact time these joints would continue to exhibit durability.

The data in Table 5 are illustrated partially in Figs. 5, 6, and 7. In Fig. 5, the rapid deterioration of urea resin glue joints is evident by the poor strength retention shown, particularly in wet shear. Fig. 6 shows the strength retention of the phenol adhesive mixes studied for the 12-month period. Good durability is evident at the conclusion of the test period. Fig. 7 contains a composite of the mixtures investigated and illustrates the superior performance of the phenol resin.

### Summary and Conclusions

Panels bonded with a urea-formaldehyde adhesive fail quite rapidly under conditions of high heat and moderate humidity. Fortification of the urea bond, in this case with mild resorcinol addition, significantly improves performance.

The phenol resin, irrespective of amount of wheat flour extension, exhibits excellent durability under high temperature and moderate humidity conditions.

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In conclusion, we do not consider the foregoing observations as final. Instead, this paper should be treated as a progress report on a long-term laboratory program, one which we hope will result in a contribution to the general knowledge of wood gluing. Tests on formulas currently available will be continued and new adhesives will be added to the program as they are developed in the future.

### Discussion

*John Yavorsky* (State University of N. Y. College of Forestry): How many specimens were tested?

*Mr. Booth:* Fifteen were used in the first tests and five in the last.

*Mr. Yavorsky:* Doesn't hot pressing usually give better results with urea resin than cold pressing?

*Mr. Booth:* Yes, it usually does.

*R. F. Blomquist* (U. S. Forest Products Lab.): Did you find any connection between delaminations on weathering and control tests on plywood at the start?

*Mr. Maxwell:* In a general sense, urea resins failed rapidly on weathering while resorcinol and phenol resin did not. Initial shear tests would indicate this pattern.

*Mr. Blomquist:* At what position (angle) were panels exposed to weather? Was any paint or other protection involved?

*Mr. Booth:* Samples were unpainted and were vertically mounted.

*Mr. Blomquist:* How do you explain complete delamination of hot-pressed, fortified urea resin while cold pressing was much better for the same glue?

*Mr. Booth:* This is attributed to the peculiarity of the particular resin involved whereby the fortifying ingredient which is incorporated is adversely affected by heat of the hot pressing operation.

*Mr. Blomquist:* What was the exposure on protected panels?

*Mr. Booth:* Temperature and humidity. Panels were protected from exposure to sun, rain, snow, etc.

*Mr. Blomquist:* Would you generally say that your results agreed with published Forests Products Laboratory results?

*Mr. Maxwell:* Yes.

*Mr. Blomquist:* What happened to wood failure values on phenol resins in 160° F., 60 per cent relative humidity test?

*Mr. Maxwell:* There was a slight reduction of per cent wood failure as panels aged in comparison to rapid drop-off in urea bonded constructions.

*Mr. Blomquist:* Have you any new ideas on short-term accelerated tests for durability other than 160° F. test?

*Mr. Booth:* We have no recommendations on this point. We like the 160° F. test with approximately 60 per cent relative humidity and believe it gives an accurate picture of glue line durability. Relative humidity is the controlling factor in this test.

*B. B. Lane* (The Lane Co.): Are results with flour extension contradictory, exposed vs. protected?

*Mr. Maxwell:* In dry shear, the 100 part flour showed better than 50 parts flour. Thick flour acts as a plasticizer. More flour gives poorer bond under wet tests.

*Alan Marra* (Univesity of Michigan): Some of the apparent contradiction between high and low flour extension may be due to the manner of expressing the results. In this case results were given as "per cent of strength retained". On that basis, a glue low in actual strength could be rated high if it did not lose much strength during the exposure.

*James F. Hamilton* (Michigan College of Mining and Technology): Please comment or give your opinion of the use of urea resin as a binder for particle board that would be used for building lumber, such as roofers or sheathing lumber.

*Mr. Maxwell:* I do not believe that urea is good for sheathing. Also phenol will not stand the steam test.

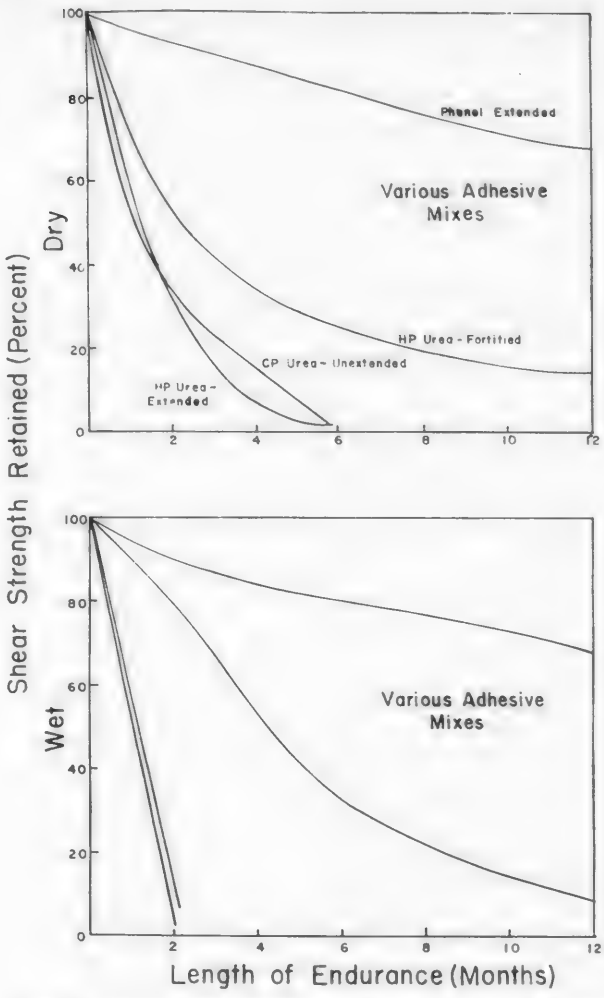


**Fig. 7.—Shear strength comparison of yellow birch panels bonded with cold and hot press urea-, fortified urea-, and phenol-formaldehyde adhesive mixes subjected to a continuous atmosphere of 160° F. and 60 per cent relative humidity.**

*Mr. Hamilton:* Considering the need for a low cost adhesive binder for composition or particle board to be used as lumber, what type of binder is offered? What is contemplated?

*Mr. Maxwell:* There is no known satisfactory adhesive for sheathing type particle board. Miller–Hofft's exposure fence of urea bonds with surface treatment is good after five years.

*Mr. Lane:* Would a reflective surface over the sheathing dissipate the heat and make urea a satisfactory adhesive for higher temperature?

*Mr. Maxwell:* Reflective surface might help some, but extent would require research to determine.

# Effect of Angular Loading on Glue Line Strength[1, 2]

JAMES T. RICE

Graduate Student, North Carolina State College, Raleigh, N. C.

**This study was conducted to learn more about the effects of vectorial stresses resulting from loading at angles other than 90 degrees on the shear strength of glue lines in laminated beech. When subjected to an angular compression stress, glue lines tended to rupture when sufficient shear stress developed. When subjected to an angular tension stress, the specimens tended to fail when the angular stress reached about 1400 pounds per square inch of glue line. Low variability of results in compression tests at 30 and 40 degree angles suggests further study as an alternate to the standard glue block shear test.**

## Introduction

GLUE LINES IN SERVICE are often subjected to some combination of forces which have components both perpendicular and parallel to the glue line. Despite this fact, the quality of a glue line is usually tested by a shearing stress parallel to the glue line.

The present research was conducted to study the effect of the component forces both parallel and perpendicular to the glue line when ruptured by applying a force at various angles. It is hoped that these results will lead to a better understanding of glue line failure and improved methods of glue line testing.

[1] This paper was originally written while the author was a Junior at Alabama Polytechnic Institute. It received the first place award in the undergraduate division of the 1953 Wood Award competition, sponsored by Vance Publishing Co., Chicago.

[2] Gratitude is expressed to Dr. Dean B. Richards of Alabama Polytechnic Institute for aid in the planning and execution of this study.

*The Author:* James T. Rice received B. S. in Forestry from Alabama Polytechnic Institute in 1954. He entered the U. S. Army Corps of Engineers upon graduation, where he served as an officer for two years. Rice is now pursuing graduate study at North Carolina State College School of Forestry.

## Materials and Methods

Kiln-dried boards of American beech (*Fagus grandifolia* Ehrh.) were planed to a uniform thickness of 26/32 inch and ripped into strips 2½ inches wide and 27 inches long. These strips were glued face to face with a resorcinol formaldehyde adhesive to form large blocks containing multiple glue lines. The glue blocks were pressed at room temperature under a pressure of 250 psi for 24 hours. After removal from the press, the specimens were cured for at least 2 weeks at room temperature before testing. These blocks were then ripped lengthwise perpendicular to the glue line and planed into strips ½ inch thick. On these strips the test specimens were laid off at various angles to the glue line as illustrated in Fig. 1. The locations in the block from which the various specimens were cut were selected at random.

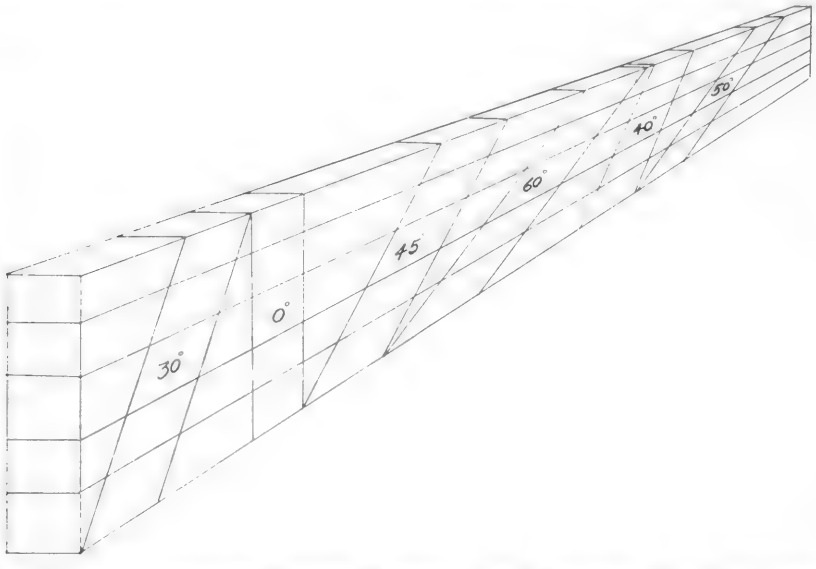


Fig. 1.—Method of laying out specimens before cutout. The different angles were randomized in position along the board.

The specimens were band-sawed out in the manner indicated in Figs. 2 and 3 for either tension or compression testing. In each specimen the portion of the glue line actually tested was ½ inch wide by 1 inch long.

The angular compression samples were tested in the apparatus shown in Fig. 4. The compression control samples (zero degree angle) were similar to standard shear block specimens but the glue line area was ½ inch wide by 1 inch long. These compression control specimens were tested in a standard shear block testing head.

The tension samples were tested in a standard plywood shear head as shown in Fig. 5. To assume a straight tension pull on a specimen it was positioned in the machine with the grips screwed up lightly, and then a load of 100 pounds was applied to pull the specimen into a line with the motion of the testing head. The grips were then screwed up firmly and the test completed.

The specimens tested in tension at 90 degrees to the glue line were loaded at a rate of 0.05 inch per minute. All other specimens were loaded at such a rate that the glue line was strained in shear at the rate of 0.25 inch per minute. The linear rate of load was calculated to yield the specified rate of load for the shear vector.

## Calculations

When a force is applied to a glue line at some angle, $\theta$, to the glue line, this force may be resolved into two components, one parallel to the glue line (called the shear component) and one perpendicular to the glue line (usually called the normal component. From the basic laws of mechanics (5), it is apparent that if the applied force is designated as F, the shear component (S) will be F cos $\theta$ and the normal component (N) will be F sin $\theta$. Each of these forces can be converted to a stress value by dividing by the glue line area.

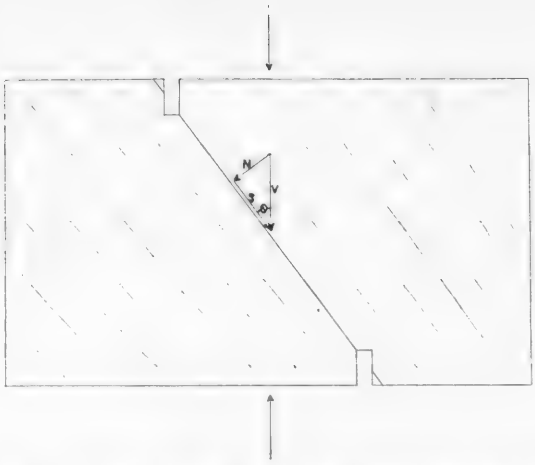


Fig. 2.—Notching technique used for the compression test samples. The diagram shows the angle $\theta$ between the testing force and the glue line, as well as the vector triangle showing the normal stress (N) and the shear stress (S).

$$N = \frac{F \sin \theta}{A} \quad \text{---------- 1}$$

$$S = \frac{F \cos \theta}{A} \quad \text{---------- 2}$$

$$V = \frac{F}{A} \quad \text{---------- 3}$$

A = Area in square inches of the glue line subjected to stress.

F = Force in pounds applied at an angle $\theta$ to the glue line.

N = Stress perpendicular to the glue line in pounds per square inch.

S = Shear stress parallel to glue line in pounds per square inch.

V = Angular stress. Stress at an angle $\theta$ to the glue line in pounds per square inch of glue line. This value is the vector sum of N and S, since they were originally resolved from it.

## Analysis and Discussion of Results

The results are shown in Table 1 and Figs. 6, 7, and 8. In considering the effect of angle of loading on the shear strength, it is apparent that the angle of loading had a marked effect on the maximum shear stress of the tension samples but had little effect on the compression samples between 0 and 50 degrees of angle. Beyond 50 degrees it was impossible to get the glue line to shear before the wood failed in compression. A least squares analysis gave the following linear regression line (4) for the compression samples.

$$S = -3.35\,\theta + 3126 \quad \text{--------- 4}$$

S = Shear stress parallel to glue line (at rupture) in pounds per square inch (see equation 2)

$\theta$ = Angle in degrees between glue line and line of action of testing force.

A statistical analysis of the above regression coefficient showed it to be non-significant with a value of 1.366 for "students t" (4). In view of this analysis, it can be assumed that the compression shear strength of the glue line in dry beech is not materially affected by angle of loading between 0 and 50 degrees but will tend to fail whenever the shear stress equals the shear strength of the glue line.

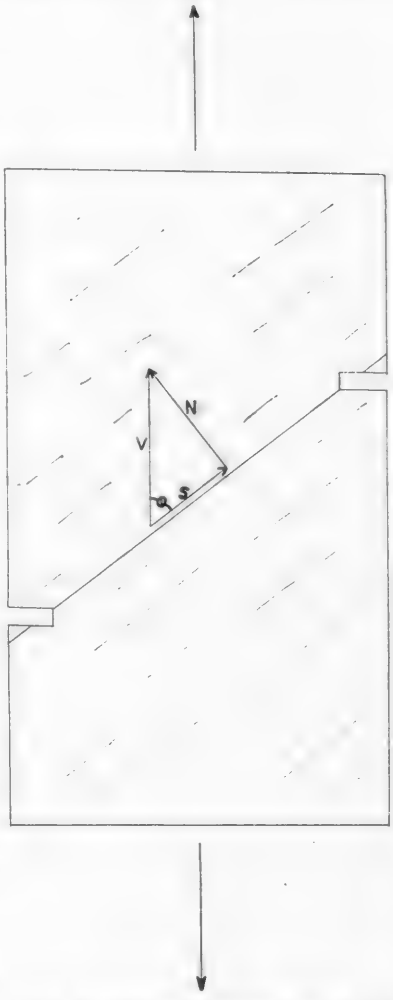


Fig. 3.—Notching technique used for the tension test samples, showing the angle $\theta$ between the testing force and the glue line, as well as the vector triangle of stress components. It can be noted here and in Fig. 2 that the wood grain is parallel to the glue line.

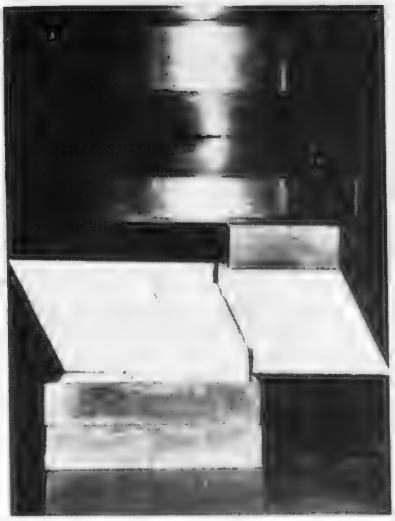

Fig. 4.—Method of testing the angular shear specimens in compression. The upper fixture is a free pivoting ball-mounted head such as is used for standard compression tests.

Since the shear strength of the tension samples varied with angle of loading, a second graph was made in which the angular stress at rupture V was plotted against the angle of loading (Fig. 7). A least squares analysis gave the following linear regression line (4) for this relationship:

Fig. 5.—Method of inserting specimens in a standard shear testing head (3). The specimen has been shifted downward slightly to give a good view of the glue line.

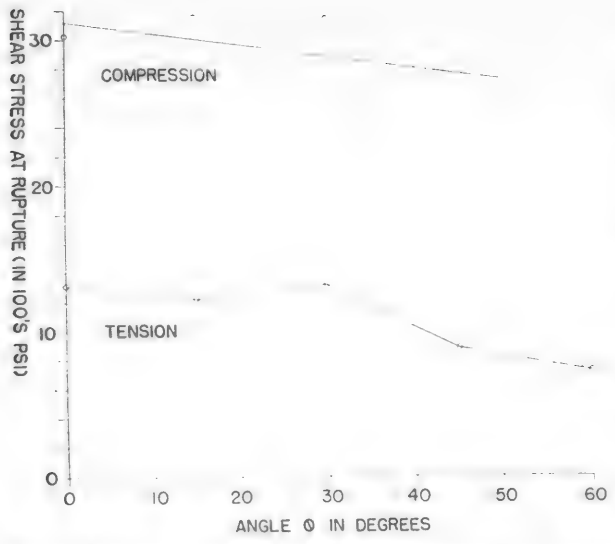


Fig. 6—Relationship between shear stress at rupture (S) and the angle $\theta$ of the testing force to the glue line.

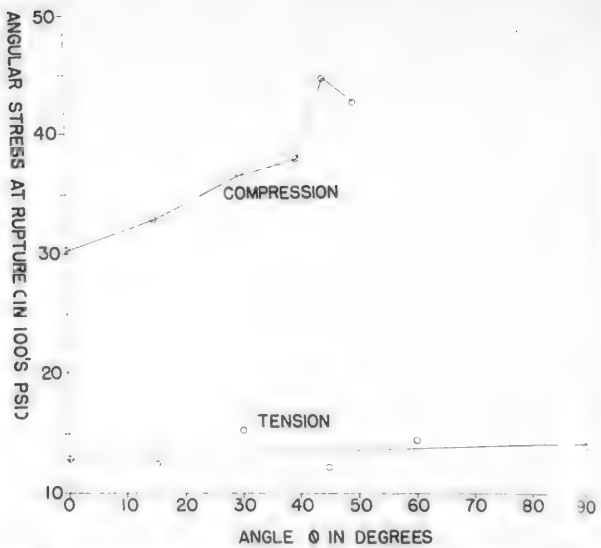


Fig. 7.—Relationship between angular stress at rupture (V) and the angle $\theta$ of the testing force to the glue line.

$V = 1.44\,\theta + 1312$ ..... 5

V = the angular stress at rupture. This is the stress at rupture in pounds per square inch (see equation 3).

$\theta$ = the angle betwen the glue line and the line of action of the testing force.

This regression coefficient gave a value for "students t" (4) of 1.206, which is not significant. This would seem to indicate that when a glue line in dry beech wood is stressed in tension at an angle, it will fail when this angular stress reaches a value of about 1400 psi of glue line. In other words, both the shear component and the normal component of the stress contribute to the failure which occurs when their vector sum equals about 1400 psi. This is in direct contrast to the behavior of the glue line in compression shear. At those angles where compression shear testing is possible, only the shear component of the testing force appears to contribute to the failure, with the normal component aiding in resisting failure.

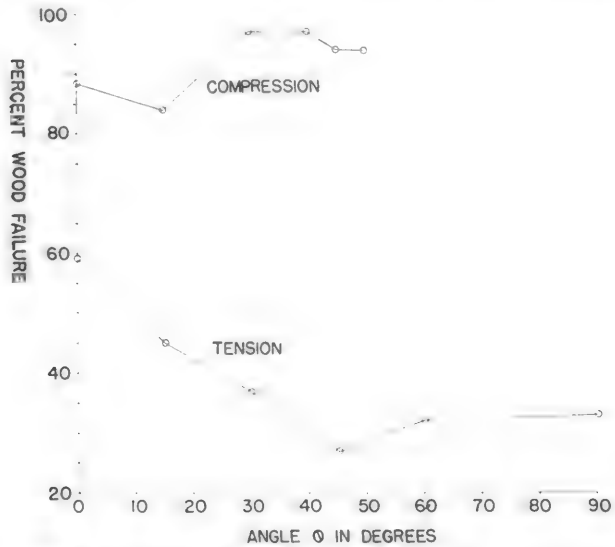


Fig. 8.—Comparison of the per cent wood failure at the glue line caused by testing in compression shear and tension shear. The angle $\theta$ is the angle between the glue line and the line of action of the testing force.

Table 1.—AVERAGE VALUES AT RUPTURE FOR VARIOUS COMPONENTS STRESSING A GLUE LINE LOADED BY A FORCE ACTING AT AN ANGLE $\theta$ TO THE GLUE LINE

| Angle $\theta$ in degrees between testing force and glue line | Average stress at rupture in pounds per square inch | | | Number of test Specimens | Coefficients of variation in per cent | Wood failure expressed as per cent of glue line area |
|---|---|---|---|---|---|---|
| | Shear Stress S | Normal Stress N | Angular Stress V | | | |
| | | | COMPRESSION TESTS | | | |
| 0 | 3016 | 0 | 3016 | 12 | 13.4 | 88 |
| 15 | 3160 | 848 | 3276 | 13 | 14.0 | 84 |
| 30 | 3158 | 1826 | 3642 | 20 | 9.6 | 97 |
| 40 | 2890 | 2425 | 3776 | 8 | 6.6 | 97 |
| 45 | 3145 | 3145 | 4450 | 24 | 14.5 | 94 |
| 50 | 2720 | 3240 | 4234 | 20 | 15.3 | 94 |
| | | | TENSION TESTS | | | |
| 0 | 1314 | 0 | 1314 | 7 | 16.2 | 59 |
| 15 | 1215 | 325 | 1257 | 9 | 23.3 | 45 |
| 30 | 1318 | 761 | 1522 | 11 | 13.4 | 37 |
| 45 | 872 | 872 | 1234 | 12 | 29.3 | 27 |
| 60 | 726 | 1256 | 1451 | 11 | 9.6 | 32 |
| 90 | 0 | 1439 | 1439 | 10 | 12.2 | 33 |

Much of the data suggests that mechanical adhesion (2,3) is important in increasing the strength in compression shear but that it contributes little to the strength in tension. The data indicate that the glue line shear strength in compression is over twice as great as the shear strength when tested in tension. It should also be noted that the per cent wood failure was conspicuously lower in the tension tests than in the compression tests (Fig. 3). An explanation of this contrast might be found in the fact that compressive forces on the glue line increase the grip of any projecting fingers of glue by pressing them deeper into the wood. In contrast, any tension on the glue line would tend to pull such projecting fingers of glue out of the wood. This would mean that the strength of a glue line in tension is largely dependent on the specific adhesion (2, 3) or chemical bonding of the glue to the wood surface.

Coefficients of variation (4) were calculated from the data and recorded in Table 1. These coefficients measure

the relative spread of the data and hence show whether or not precision could be expected if the method were employed as a standard testing technique. As seen in Table 1, the variations for the angular compression tests were as low as those for standard shear, and in the region around 30–40 degrees they present an even lower variation. This could be due to the normal component reducing chance occurrence of tension stresses acting on the glue line.

### Applications

. The fact that the angular tension shear tests caused a fairly high per cent of glue failure (i.e. a low per cent of wood failure) suggests that it is a more exacting test of the glue line than are any of the compression tests. This high percentage of glue line failure also affords a good view of the glued surface after testing and would help in spotting glue line deficiencies. The fact that these tests can be run with a standard plywood shear head means a low investment in testing equipment.

2. While the technique was not explored in this study it seems possible that testing a wet glue line in tension might show promise as an accelerated durability test. This could be a straight tension test at 90° to the glue line or further experimentation might substantiate the lower coefficient of variation found in these data at an angle of around 60°.

3. The simplicity of the technique and equipment required for the compressive shear tests and their low coefficients of variation at angles of 30 and 40 degrees suggest them as possible alternates to the standard glue block shear tests.

4. The effect on the glue line strength of the different components of stress should be considered in any design work where strength is a critical factor.

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# Training for Quality Control Work[1]

A. E. WYLIE

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**Discusses the importance and status of training for quality control in wood processing. Methods of training quality control supervisors are covered and the need is emphasized for bringing about understanding of a quality program's aims at various levels in an organization. Literature is reviewed on various aspects of quality control, including principles, setting up a program, and training of personnel.**


THE IMPORTANCE OF QUALITY CONTROL in industry and in human activities in general is indicated by the growth and size of the American Society for Quality Control. That the problem of quality control pervades all business activities, not production alone, is reflected quite clearly by the broad scope of the activities of the Society members. In 1946 the number of firms employing members of the Society was 469. The number in 1955 was 6250, a 13-fold increase. In the same period there was a six-fold increase in membership to the present figure of about 10,000 in the tenth year of the organization.

Application of the techniques of statistical control is being made in such areas as accounting, clerical work, sales and marketing, purchasing, and research, as well as in all production activities. The tools of statistics are found to be necessary for efficient research, production, and management activities to an ever-increasing extent.

The woodworking industry is not fully aware of the valuable contributions of statistics in controlling quality. It has not shown the progressiveness displayed by some other industries. On the other hand, modern quality control procedures are being used in many phases of the woodworking industry. The methods are being used in connection with the production of veneer and plywood, lumber, various building board materials, millwork, furniture, flooring, dimension stock, turnings, toys, athletic goods, and many other items. The variety of applications to products and activities is growing, but the number of organizations involved is small indeed. The use of statistical methods is increasing; potential use is almost unlimited. Realization of an optimum use of statistical quality control in wood processing depends upon availability of men trained in quality control methods.

The need for quality control men is beginning to be recognized by managers of wood-using plants. Many are now looking for men to fill positions in wood-processing plants. Also, requests made to forestry schools for information on setting up quality control programs and on training activities reflect a growing interest in quality control.

### Opportunities for Advancement

Present and future requirements for quality control engineers in the woodworking industry are great. This is especially true because of rapid advancement of quality control men to positions of greater responsibility within an organization. The quality control engineer, realistically assigned, occupies a unique position between management and production. He has an excellent opportunity to learn the overall operation of a business in performing his assigned duties. As a result he should sooner become eligible for promotion. The attributes of a successful quality control supervisor

[1] Presented at meeting of Quality Control Division during FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

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are quite similar to those desired in men in higher management levels.

If the potential development of quality control in wood processing is to be realized in a reasonable time, greatly increased effort in providing qualified personnel will be required. As indicated by Henry (11)[3] and Olds (17), the supply of trained personnel for quality control in industry is far less than the demand. It is probably safe to estimate that the need for quality control engineers exceeds the need for engineers in any other single category.

The problems of meeting the need for quality control engineers is of great importance to the Forest Products Research Society. In considering the problem it is necessary to emphasize the special training that is vital to the success of the man directing quality control activities. The character and extent of this training has been described by several authors including Deming (5), Grant (8), Henry (11), and Olds (17). Also, Henry (11) and Olds (17) have emphasized the need for including work in statistical quality control in all engineering education programs. Some work in quality control should be given to all forest products students.

## Job Qualifications

The qualifications of quality control engineers are so little known that it is desirable to give special attention to references on the subject. Juran (14) gives a job specification which requires an engineering degree or equivalent; includes courses in industrial management, manufacturing processes; engineering economics, methods, and procedures; statistics, quality control, analysis of data; and three to five years in industry dealing with processes and products. Reynolds (19) states that if you require quality control engineers fully trained, then you require a level of mental ability and training comparable to those for design engineers, C.P.A.'s or research chemists. The statistical administrator, according to Deming (5), should have the qualifications of the administrator in any other part of plant operation and in addition know statistical principles and the power of statistical technique.

The quality control engineer requires the assistance of men who may have various degrees of training. Personnel to meet the demand for quality control activities may obtain training in several ways. The means include in-plant courses, short courses at educational institutions, evening courses sponsored by the American Society for Quality Control and technical institutes, self education through textbooks, and special area training in four-year professional programs.

The men selected for training in quality control should possess attributes and potential that correspond with the level of work they are expected to do. Deming (5) says the main requirement for workers in the manufacturing plant who attend short courses is an open mind and eagerness to learn. Students that seem to do best are those with some experience in a manufacturing plant, a fairly good schooling, with a liking for figures and for deduction from numerical data (5). Careful attention should be given to the selection of quality control trainees.

Of primary concern is the extent to which men have been prepared for quality control work in wood processing. The number of college-trained men having had statistical training has been a mere trickle in contrast to the flood of literature on the subject of quality control (11). Deming (5) believes the instruction on quality control in engineering programs is far out of date and therefore inadequate. Both viewpoints apply to forest utilization. In general, the work in quality control offered by forest products departments is inadequate. In most instances, if provided at all, the instruction forms a part of a general course in production. In a few schools a basic course in statistics is required. This may be followed by a course in quality control applied to wood processing.

With reference to the qualifications of a quality control engineer given above, it follows that graduate work is necessary for most forest products students who wish to prepare for administration of the quality control function. Graduate students in forest products may take the opportunity in a few institutions to obtain major training in statistical quality control.

## Other Training Systems

Smith (21) reported that two forestry schools had offered short courses in quality control to a total of 59 men up to June 1955. There has been general failure to follow the training provided with application of the techniques and procedures by the men upon return to their respective plants. This has occurred for several reasons. In some instances management did not understand the requirements for beginning a realistic quality control program. In other cases a poor choice was made in the selection of the man to send for training.

In-plant courses in quality control are rare in wood processing. Larger organizations such as automobile companies have set up rather comprehensive programs of training. They prepare instruction manuals for their own particular purposes. Literature devoted to discussion of such programs should be of interest to wood processors. The bibliography contains several articles on this subject.

Self-education methods are highly recommended for supplementary training. They have been of only slight importance as an exclusive mean of providing quality control personnel for the wood processing industry. The same is true for industry in general. This is likely to continue to be true due to the nature of the technical literature on quality control.

Consultants are a source of assistance in the initial stages of a quality control program and periodically thereafter. The use of such services may be for in-plant training inasmuch as the need for permanent personnel will always be present.

## Understanding at Other Levels

The discussion so far has dealt with training personnel directly concerned with carrying out the quality control assignment. Deming (5) points out that there are four groups of personnel that require quality control training. They are management, statistical administration, research, and workers in manufacturing. Juran (14) presents a thorough discussion of the need for, and how to bring about, quality-mindedness at various levels in an organization.

The success of a quality control program depends upon the general understanding of the aims of the program within the several groups involved. Modern methods of quality control have been used far less than would have been true otherwise, simply because management has lacked the understanding necessary to support the quality control engineer. Education at the management level in appreciation of the value and special problems of the quality control engineer is of utmost importance in wood-processing industries. Authors of FPRS papers on quality control indicate that they are aware of this in their presentations.

Probably the most effective training for quality control, outside regular college programs, is that given in evening courses to men who have opportunities to apply the knowledge as it is made available and to seek advice in this connection from the instructor. Information on the availability of such instruction can be obtained from the American Society for

[3] Numbers in parentheses refer to the bibliography.

Quality Control. Most of this kind of training is sponsored by the ASQC. The organization sponsors more than 30 annual conferences and meetings each year ranging from one through two weeks.

The need for quality control engineers exceeds the demand. This is recognized by many plant managers. Training in quality control is needed at several levels in wood products plants. The FPRS Quality Control Subject Matter Division should continue to support training programs and in any manner possible increase the present effort. The Division should be concerned with providing information as to availability and requirements for training in wood processing and should look for means of assisting wood products plant managers in obtaining personnel to carry on quality control activities.

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# Decay and Toughness Losses in Southern Pine Infected by *Peniophera*[1]

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**Exploratory tests were conducted to determine decay and toughness losses in peeled longleaf pine bolts, 5 feet in length and 8 to 11 inches in diameter, during 6 to 13 weeks of summer storage in Mississippi. Drying conditions simulated those encountered in some commercial stacks of poles, posts, and peeled pulpwood. Averages were calculated for percentage of decay, losses in specific gravity due to decay, and reduction in toughness due to decay at the end of 6, 10, and 13 weeks.**


## Introduction

THE MOST COMMON EARLY DECAY during seasoning or storage of southern pine poles, posts, ties, and pulpwood is caused by *Peniophora gigantea*. This fungus is distributed over much of the United States, but is particularly prevalent in the South and Southeast. Damage caused by it in this territory is most rapid during the months of May to October, but continues slowly even during the winter period. Attempts to prevent losses by rapid drying or by surface application of fungicidal solutions usually have been unsuccessful, except in such small items as peeled posts and pulpwood. Consequently, large products can seldom be fully seasoned with safety in the South. Likewise, rough pulpwood cannot be stored for long periods without heavy damage.

*Peniophora* often is first evident as a whitish, mycelial growth on the surface of the wood or bark. On the ends of timbers, this growth may appear as radiating streaks or fan-like patches. If fruiting bodies develop, they occur as smooth, flat, wax-like patches of varying size that are white, slightly yellowish, or smoky-gray in color. These patches become brittle and parchment-like on dried surfaces, and can be easily separated from the wood. In rough pulpwood, the surfaces of the wood below patches on the bark are almost always bleached to a white or creamy color. Infected peeled wood, on the other hand, may show no outward mycelial growth or bleaching of the wood surfaces.

Early stages of infection by *Peniophora* are difficult to detect, because only slight changes in color and con-


[1] This work was done in cooperation with the Southern Forest Experiment Station, New Orleans, La.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.



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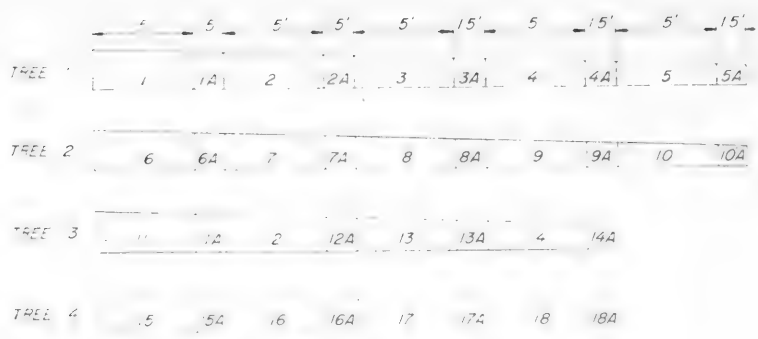


Fig. 1.—Identification of test sections.

dition of the wood take place. The recent development of a color indicator test (3),[3] however, has simplified the detection of these incipient infections. In later stages of decay, the wood may be greatly softened in the springwood part of growth rings, but open pockets are seldom formed. Chemical analyses of infected wood indicate that both the cellulose and lignin have been attacked and there is little change in the relative proportions of these components (4).

The prevalence of *Peniophora* has long been recognized, but early investigators regarded it as harmless. In ties, for instance, Humphrey (1) stated that inspectors need not discriminate against it because appreciable rot was not caused. In 1940, however, Richards and Chidester (6) described laboratory tests in which losses of as much as 35 per cent in work to maximum load were produced by the fungus. They concluded that *Peniophora* might reduce strength of wood appreciably in practice, and that damage from it during storage should be avoided. Later field studies on southern pine pulpwood (2) disclosed that this fungus was a major source of damage during prolonged storage, and that losses in specific gravity and pulp yields of rough pulpwood often reached 10 per cent during six months of storage. Recently, Orman reported (5) that *P. gigantea* was the principal decay organism in Corsican pine posts during seasoning in New Zealand, and that appreciable losses in toughness were indicated for posts seasoned in the open.

Despite evidence to the contrary, the viewpoint that *Peniophora* is unimportant has tended to persist. At the same time, suspicion has developed that losses in strength due to this fungus have been a contributing factor in certain perplexing cases of early breakage of preservative-treated and untreated products of southern pine. These divergent viewpoints have made the need for more information obvious, particularly on strength losses in wood stored under field conditions and exposed to natural infection.

This report describes some exploratory tests to determine toughness losses of longleaf pine exposed to natural *Peniophora* and other fungus infection during 6 to 13 weeks of storage. The test material consisted of 5-foot peeled bolts, 8 to 11 inches in diameter, that had been stored in a small pile between July 24 and October 20, 1953, at the Harrison Experimental Forest, Saucier, Miss. Tests of the toughness of this material were conducted at the U. S. Forest Products Laboratory, Madison, Wis.

## Experimental Methods

**Wood Material:** Four longleaf pine trees, 10 to 11 inches in diameter and 28 to 30 years in age, were selected to supply sapwood test material with a minimum of growth irregularities. These trees were cut into alternate 5-foot bolts and 1.5-foot sections, which were peeled immediately. By cutting to a minimum diameter of about 8 inches, 18 pieces of each length that ranged between 8 and 11 inches in diameter were obtained from the four trees. Each piece was so marked that its relation to a specific tree and position in the tree could be identified. The system of cutting the trees and marking the pieces is illustrated in Fig. 1.

After the sections were peeled and marked, the 1.5-foot sections (marked with the suffix "A"), which were to serve as uninfected control material, were split lengthwise into halves to facilitate drying. They were then soaked for 24 hours in an aqueous fungicidal solution containing 5 per cent of sodium pentachlorophenate, and were finally stored open-piled in a building.

The 5-foot bolts were stacked immediately after they were peeled in a small pile that was erected about 1 foot above ground in the open at the Harrison Experimental Forest. The completed pile consisted of three bottom and top layers of nontest bolts, with three layers of six bolts each of test material in the center. Although the bolts were bulk piled, the small size and exposed condition of the pile permitted drying that was no slower than occurs in at least some commercial stacks of poles and peeled pulpwood. Two of the test bolts were eventually discarded because of excessive checking or other abnormalities.

After approximately 5, 9, and 12 weeks of storage, either five or six bolts were removed from the pile, and a 2-foot piece was cut from one end of each bolt. These pieces, along with an equal number of the 1.5-foot control sections that had been adjacent to the respective pieces in the tree, were immediately shipped to the U. S. Forest Products Laboratory. Since shipment required 7 to 10 days and the bolt pieces were still wet enough for continued decay development during transit, the storage periods for the bolts were considered to be 6, 10, and 13 weeks. When the material arrived in Madison, the bolt pieces were placed immediately in a cold room maintained at 40° F. to arrest further decay; similar protection was unnecessary for the uninfected and treated control sections, which were practically air dry. Each of the three shipments usually included at least one bolt piece and its matched control section from each of the four original trees.

**Decay and Specific Gravity Determinations:** Before the wood was processed for toughness tests, 1-inch disks were cut from both ends of each bolt and its control section. These disks were used for a determination of: 1) The amount and type of decay in the stored bolts, and 2) possible losses in specific gravity of the bolts during storage. The amount and type of decay were ascertained by visual examination, probing, and the use of a color indicator for *Peniophora* decay. The specific gravity of the disks was determined from their volume when green and weight when oven dry. Since these data were based on the entire cross sections, they cannot be applied specifically to the small toughness test specimens that were cut from the same bolt.

**Toughness Tests:** The bolt pieces and control sections were first sawed into radial flitches 1¼ inches wide and 22 and 16 inches long, respectively. The 22-inch flitches were slowly kiln-dried at 130° F. to a moisture content of about 15 per cent. The kiln-dried flitches were then conditioned to moisture equilibrium in a room maintained at 65 per cent relative humidity and 70° F. All air-dried control flitches were conditioned at 65 per cent relative humidity and 70° F. immediately after they were cut into flitches. After the flitches

[3] Numbers in parentheses refer to literature cited.

were conditioned, toughness test specimens, 5/8 by 5/8 by 12 inches in size, were cut from each flitch at 0.5 to 1.5 inches (outer) and 2.0 to 3.0 inches (inner) from the bark surface. The specimens were then placed in the conditioning room for at least another 10 days before they were tested.

Each specimen was tested in the Forest Products Laboratory toughness testing machine over a span of 9¾ inches under third-point loading. The load was applied to the tangential face nearest the bark surface. Ten specimens were selected from each bolt piece and its control section; six came from the outer zone and four from the inner zone. These specimens were selected at random from those available, except that specimens with perceptible drying checks or abnormal amounts of diagonal grain were discarded. Since the 5/8-inch specimens were sawn from different parts of a 1-inch zone, those from a given zone varied somewhat in the relative amounts of springwood and summerwood.

## Results

**Decay Infection and Specific Gravity:** Table 1 summarizes the data on average decay infection and specific gravity as determined from cross sections of the bolts. Fig. 2 illustrates the amount and distribution of infection in some of the bolts.

Decay or other fungus infection was entirely absent from all control sections. Attempts to isolate pure cultures of the fungus responsible for decay in the stored material were unsuccessful because of contaminating organisms. The appearance of the infected wood and the mycelial growth from infected areas in wood incubated in moist chambers indicated, however, that most if not all of this decay was caused by *Peniophora gigantea*.

For the three storage periods, the amount and type of infection and the indicated losses in specific gravity due to decay were as follows:

1. From 20 to 40 per cent of the cross sectional area of the bolts stored for six weeks showed decay infection; the average for the group was 31 per cent. The decay occurred as scatterred patches or sectors of slightly yellowed wood in an incipient stage of infection. There was no perceptible softening of the wood in infected areas. Losses in specific gravity associated with decay were slight, and averaged less than 1 per cent. In addition to decay, 5 to 15 per cent of the cross-sectional area was discolored by blue stain fungi.

Patches of yellowed wood caused by decay infection covered 45 to 65 per cent of the cross- sectional area of the bolts stored for ten weeks, and averaged 58 per cent for the group. Except for a few spots of slightly softened wood, the infection was incipient. Indicated losses in specific gravity associated with decay ranged from less than 2 to almost 4 per cent, and averaged about 3 per cent. Blue

**Table 1.—SUMMARY OF DATA ON AMOUNT OF DECAY, SPECIFIC GRAVITY, AND TOUGHNESS VALUES OF TEST SPECIMENS**

| Bolt No.* | Decay† Per cent | Specific gravity‡ Average | Specific gravity‡ Loss Per cent | Toughness§ Outer zone In.-lb. | Toughness§ Inner zone In.-lb. | Toughness§ Average In.-lb. | Toughness§ Loss Per cent |
|---|---|---|---|---|---|---|---|
| | | BOLT GROUP STORED 6 WEEKS | | | | | |
| 1A | 0 | 0.540 | | 304 | 307 | 306 | |
| 1 | 20 | .540 | 0 | 265 | 249 | 257 | 16 |
| 7A | 0 | .550 | | 314 | 343 | 329 | |
| 7 | 30 | .548 | .4 | 252 | 247 | 250 | 24 |
| 9A | 0 | .506 | | 251 | 323 | 287 | |
| 9 | 28 | .505 | .2 | 254 | 249 | 252 | 12 |
| 13A | 0 | .600 | | 464 | 348 | 406 | |
| 13 | 35 | .592 | 1.3 | 338 | 334 | 336 | 17 |
| 17A | 0 | .527 | | 243 | 256 | 250 | |
| 17 | 40 | .522 | .9 | 226 | 219 | 223 | 11 |
| Av. | 31 | | .6 | 15.3 | 17.6 | 16.5 | 16 |
| | | BOLT GROUP STORED 10 WEEKS | | | | | |
| 2A | 0 | 0.527 | | 304 | 232 | 268 | |
| 2 | 63 | .508 | 3.6 | 208 | 181 | 195 | 27 |
| 6A | 0 | .594 | | 322 | 309 | 316 | |
| 6 | 65 | .571 | 3.9 | 201 | 182 | 192 | 39 |
| 8A | 0 | .532 | | 304 | 321 | 313 | |
| 8 | 60 | .523 | 1.7 | 263 | 230 | 247 | 21 |
| 12A | 0 | .628 | | 460 | 301 | 381 | |
| 12 | 45 | .610 | 2.9 | 346 | 256 | 301 | 21 |
| 16A | 0 | .563 | | 304 | 321 | 313 | |
| 16 | 58 | .541 | 3.9 | 198 | 274 | 236 | 25 |
| Av. | 58 | | 3.2 | 28.2 | 24.3 | 26.4 | 27 |
| | | BOLT GROUP STORED 13 WEEKS | | | | | |
| 3A | 0 | 0.510 | | 270 | 222 | 246 | |
| 3 | 63 | .486 | 4.7 | 181 | 153 | 167 | 32 |
| 5A | 0 | .470 | | 202 | 137 | 170 | |
| 5 | 78 | .452 | 3.8 | 145 | 86 | 116 | 32 |
| 11A | 0 | .641 | | 448 | 439 | 444 | |
| 11 | 40 | .631 | 1.6 | 357 | 414 | 386 | 13 |
| 14A | 0 | .592 | | 399 | 421 | 410 | |
| 14 | 63 | .568 | 4.1 | 218 | 193 | 206 | 50 |
| 15A | 0 | .574 | | 388 | 396 | 392 | |
| 15 | 55 | .562 | 2.1 | 265 | 269 | 267 | 32 |
| 18A | 0 | .518 | | 255 | 299 | 277 | |
| 18 | 73 | .493 | 4.8 | 174 | 175 | 175 | 37 |
| Av. | 62 | | 3.5 | ‖31.7 | 32.6 | 32.1 | 33 |

*Specimens labeled A represent the uninfected control sections.

†Average per cent of cross section of bolt showing decay, based on two 1-inch disks cut from the ends of each piece. These percentages did not necessarily represent the amount of decay in the small toughness specimens that were cut from the bolt piece.

‡Average specific gravity based on weight when oven dry and volume when green of two 1-inch cross-sectional disks cut from the ends of each stored bolt piece and each control section. The per cent loss represents the ratio: $\frac{\text{stored bolt}}{\text{control A}}$ Specific gravity was not determined for the individual toughness specimens.

§Toughness values were usually based on six specimens from the outer zone (0.5 to 1.5 inch) and four specimens from the inner zone (2.0 to 3.0 inch from the bark surface) of the bolts.

‖Average per cent difference between stored bolt and control section averages for group.

Fig. 2.—Decay infection (light-colored areas) in some of the test bolts as disclosed by spraying surfaces of cross sections with Alizarin Red solution. Section 16–A represents uninfected control wood. The remaining sections are from material stored for six weeks (1–B) to ten weeks (8–B).

stain discoloration was variable and ranged from 5 to 25 per cent of the cross-sectional area.

3. Decay infection was present in 40 to 78 per cent of the cross-sectional area of the bolts stored for 13 weeks, and averaged 62 per cent for the group. Perceptibly softened wood occurred in spots in all bolts except No. 11, but there were no open pockets of decay. Indicated losses in specific gravity due to decay ranged from less than 2 to almost 5 per cent, and averaged about 3.5 per cent. Blue stain discoloration varied from 5 to 60 per cent. In some pieces, earlier staining obviously had been obliterated by the bleaching action of decay fungi.

The specific gravity data for the uninfected control material were in line with reported trends in southern pine. Thus there was a progressive decrease in specific gravity from the butt toward the top of each of the original four trees (Table 1). For the first tree cut, the specific gravity values were 0.540 for 1A, 0.527 for 2A, O.510 for 3A, and 0.470 for 5A. Similar reductions from butt to top were shown by the other trees.

**Toughness Values:** Average toughness values for the small specimens cut from the infected, stored material and uninfected, control material are summarized in Table 1.

Direct comparisons cannot be made between the specific gravity and toughness values, because specific gravity was determined for the entire cross sections, not for the individual specimens tested for toughness. For the infected, stored bolts, another complicating factor was the variable distribution of decay, which undoubtedly had different effects on specific gravity of toughness specimens from the same bolt. Neverthless, high toughness values for the small specimens were generally associated with high specific gravity values for the corresponding cross sections.

Considering toughness values only, there was an indicated average loss in toughness of about 16 per cent in the bolts stored for six weeks. All bolts showed some loss, and the range for the group was from 11 to 24 per cent. Individual toughness specimens appeared to reflect the scattered distribution of decay in this group. For example, a number of specimens from stored wood were similar in toughness to those from the corresponding control wood, whereas others were appreciably lower than the average loss for the group. After ten weeks of storage, an average loss of 27 per cent was indicated for the stored group, with a range among the five bolts of from 21 to 39 per cent. Individual toughness specimens still reflected variable decay distribution, but to a lesser extent than in the group stored for six weeks. After 13 weeks, losses in toughness averaged 33 per cent, and ranged between 13 and 50 per cent among the six bolts. Except for bolt 11, practically all toughness specimens from stored wood showed lower toughness values than those from the corresponding control wood.

In general, losses in toughness of the stored wood were not greatly different for the specimens taken from the outer and inner zones of the bolts.

## Discussion

Indications from this exploratory study were that the toughness of the stored wood decreased approximately 2 to 3 per cent per week during the 6- to 13-week period. Except for the final two weeks, the storage period covered a time of the year in Mississippi when decay and associated strength losses are most rapid. On the basis of other studies, similar material stored in the same manner between October and April probably would show only ½ to 1/3 as much decay and toughness loss as occurred in these tests.

Toughness tests were used as a criterion in this work because they reflect the effects of decay on strength properties more quickly than do comparisons based on other methods of test. On the other hand, toughness is of minor importance in the use of southern pine round stock for such purposes as poles. It is impossible to translate toughness values directly into values for bending or other strength properties. It is believed safe, however, to assume that the percentage losses in bending of the test material would have been appreciably lower than those indicated for toughness.

There were limitations in the sampling and matching of the toughness test material in this exploratory study. As a result, the variability among these toughness values for a given group of specimens was probably greater than usually occurs when closely matched specimens are tested. Although the general trend of the data is not questioned, more extensive experimentation is needed to determine whether the indicated magnitude of toughness losses with increase in length of storage is typical in practice. Also, storage at different seasons of the year should be compared for an adequate attack on all aspects of the problem.

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# An Evaluation of Factors Affecting the Rate of Drying of Round Western Hemlock During the Boiling Under Vacuum Process

W. M. CONNERS and G. BRAMHALL

**A series of experiments was conducted to establish a mathematical relationship between factors which cause the removal of moisture from wood and the moisture removed or condensate collected. It is pointed out that the equation derived is an approximation and that additional experiments may necessitate modification.**

## Introduction

WHEN WOOD IS SUBMERGED in an oil-type preservative in a closed retort and air is removed by a vacuum pump, the moisture boils from the wood as steam and may be condensed, collected, and measured. The authors have published the results of experiments which showed the relation between the moisture content of western hemlock heartwood and the bath temperatures with corresponding vacua required to start the boiling process.[2]

The results of these experiments were represented graphically by a series of curves for western hemlock of several moisture contents in the range of 9 to 24 per cent, these curves being similar to the saturated steam curve which represents the vacuum and temperature at which saturated steam and water are in equilibrium. Higher vacua or temperatures are required to boil water from wood than are required to boil free water, and the difference becomes greater as the moisture content in wood decreases. These curves showed that the higher the temperature and vacuum, the greater would be the amount of water boiled from wood.

Factors which affect the rate of heating would also be expected to affect the rate of boiling. Such factors have been shown by MacLean[3] to be time, specific gravity, moisture content, and size of specimens.

Factors which are measurable and which influence the amount of water boiled from wood are:

1. Bath temperature
2. Vacuum
3. Time
4. Size of specimens
5. Initial moisture content
6. Specific gravity

If all the factors except one could be maintained constant while the remaining one were varied, an evaluation of each factor could be made in turn. Then an equation showing the relation between the amount of water or condensate and all the contributing factors could be derived. This is a standard procedure with homogeneous materials. However, wood is not homogeneous and its properties are such that it is impossible to select round logs of uniform diameter, moisture content, and specific gravity as experimental specimens, and it would in any case be impossible to keep them in their original condition for the time required to conduct the necessary number of experiments. Thus a formula which would represent the amount of condensate could not be derived by this method.

Another method is to assume a specific function for each variable. When the assumed functions approach the truth, the amounts of condensate as calculated by the formula approach the actual amounts for all experiments. Using successive approximations, a formula for the amount of condensate may be found which gives values closest to the actual amounts. While such a procedure involves tedious computations with the powers, roots, logarithms, and trigonometrical functions of the several variables, it holds promise of establishing a mathematical relation between the factors which cause the removal of moisture from wood and the moisture removed or condensate collected. However, it must be emphasized that such an equation can only be an approximation, for which the experiments reported in this article are hardly more than sufficient for its derivation.

## Experimental Procedure

In order to collect experimental data from which to calculate a formula, freshly cut western hemlock logs ranging from 12 inches to 18 inches diameter were obtained in 34-foot lengths. On arrival they were peeled and sprayed with a water-soluble sap stain preventive, protected on both ends with a generous application of resorcinol glue, and covered with canvas to retard evaporation. Before the logs were treated, they were cut to 16-foot lengths and the fresh cuts were again protected with resorcinol glue.

Each 16-foot log was treated alone in the retort. A series of 14 experiments were run in which temperatures were maintained constant through a range extending from 150° to 210° F. The vacuum, while constant in each experiment, ranged throughout the series from the lowest noticeable boiling point up to 28 inches maximum. Readings of water boiled from the wood were recorded hourly for approximately 60 hours. The complete series of treatments extended from September 14, 1954 to June 27, 1955.

## Results

Radii, weights, annual rings, bath temperatures, vacua, and condensate removed at 24-, 41- and 60-hours periods are recorded in Table 1. The data shown in Table 2 was derived from Table 1, and reduced to a cubic foot basis.

A contribution from the Vancouver Laboratory, Forest Products Laboratories of Canada, Division of the Forestry Branch, Department of Northern Affairs and National Resources.

[2] Bramhall, G. and W. M. Conners. 1955. Vacuum pressures in western hemlock heartwood for boiling under vacuum in creosote. For. Prod. Jour. V (4):267–271.

*The Authors:* W. M. Conners received B. A. from U. of Toronto, formerly was treating editor and manager of treating plant for Canada Creosoting Co. Ltd. He joined the Vancouver laboratory in 1948 as head of the Wood Preservation Unit.

George Bramhall received B. A. Sc. from U. of British Columbia. He was research and wood engineer at Vancouver Plywoods from 1947–49, has been forest products engineer at Vancouver Laboratory since 1949.

[3] MacLean, J. D. 1940. Relation of wood density to rate of temperature change in wood in different heating mediums. Proc. AWPA, pp. 220–248.

Table 1.—RECORDED EXPERIMENTAL DATA

| Charge No. | (1) Number of annual rings in cross sect. | (2) Init. wt. lb. | (3) Average radius ft. | (4) Volume Cu. ft. | (5) Bath temp. °F. | (6) Delay reaching temp.-hrs. | (7)* Vacuum in. Hg. | (8) Condensate 24 hrs. lb. | (9) Condensate 42 hrs. lb. | (10) Condensate 60 hrs. lb. |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | | 586 | .52 | 13.6 | 150 | 3 | 28 | 34 | 55 | 65 (59 hrs.) |
| 4 | 55 | 489 | .546 | 15.0 | 170 | 9 | 28 | 30 | 49 | 57 (53 hrs.) |
| 5 | 56 | 626 | .567 | 16.2 | 190 | 9 | 28 | 58 | 103 | 119 (53 hrs.) |
| 8 | 60 | 455 | .512 | 13.2 | 190 | 9 | 19.5 | 13 | 28 | 38 |
| 9 | 54 | 353 | .448 | 10.0 | 190 | 12 | 22 | 24 | 40 | 49 |
| 10 | 52 | 567 | .573 | 16.5 | 190 | 9 | 25 | 38 | 63 | 83 |
| 12 | 42 | 494 | .512 | 13.2 | 190 | 9 | 28 | 51 | 81 | 105 |
| 23 | 40 | 394 | .478 | 11.5 | 190 | 9 | 28 | 37 | 57 | 73 |
| 13 | 56 | 515 | .553 | 15.4 | 210 | 9 | 16.7 | 20 | 41 | 53 |
| 14 | 44 | 441 | .506 | 13.0 | 210 | 12 | 20 | 29 | 53 | 69 |
| 15 | 46 | 742 | .596 | 17.9 | 210 | 18 | 24 | 29 | 73 | 105 |
| 20 | 32 | 425 | .452 | 10.3 | 210 | 12 | 24 | 39 | 70 | 89 |
| 21 | 40 | 550 | .542 | 14.7 | 210 | 9 | 24 | 34 | 65 | 89 |
| 22 | 49 | 494 | .530 | 14.2 | 210 | 9 | 23 | 51 | 79 | 93 |

Each charge consisted of one only 16-foot long specimen.
*Vacuum shown in this column was reached in 2 hours or less and maintained constant.

Table 2.—DERIVED DATA FROM EXPERIMENTAL RECORDINGS

| Chage No. | (1) Init. wt. (D) lb/cu. ft. | (2) One-third delay reaching temp.-hrs. | (3) Absolute pressure P in. Hg. | (4) Condensate 24 hrs. lb/cu. ft. | (5) Condensate 42 hrs. lb/cu. ft. | (6) Condensate 60 hrs. lb/cu. ft. |
|---|---|---|---|---|---|---|
| 2 | 43.1 | 1 | 2 | 2.5 | 4.0 | 4.8 (50 hrs.) |
| 4 | 32.6 | 3 | 2 | 2.0 | 3.3 | 3.8 (55 hrs.) |
| 5 | 38.6 | 3 | 2 | 3.6 | 6.4 | 7.4 (53 hrs.) |
| 8 | 34.5 | 3 | 10.5 | .99 | 2.1 | 2.9 |
| 9 | 35.3 | 4 | 8 | 2.4 | 4.0 | 4.9 |
| 10 | 34.3 | 3 | 5 | 2.3 | 3.8 | 5.0 |
| 12 | 37.4 | 3 | 2 | 3.9 | 6.1 | 8.0 |
| 23 | 34.3 | 3 | 2 | 3.2 | 5.0 | 6.3 |
| 13 | 33.5 | 3 | 13.3 | 1.3 | 2.7 | 3.8 |
| 14 | 34.0 | 4 | 10 | 2.2 | 4.1 | 5.3 |
| 15 | 41.5 | 6 | 6 | 1.6 | 4.1 | 5.9 |
| 20 | 41.2 | 4 | 6 | 3.8 | 6.8 | 8.6 |
| 21 | 37.4 | 3 | 6 | 2.3 | 4.4 | 6.1 |
| 22 | 34.8 | 3 | 2 | 3.6 | 5.6 | 6.6 |

Each charge consisted of one only 16-foot long specimen.

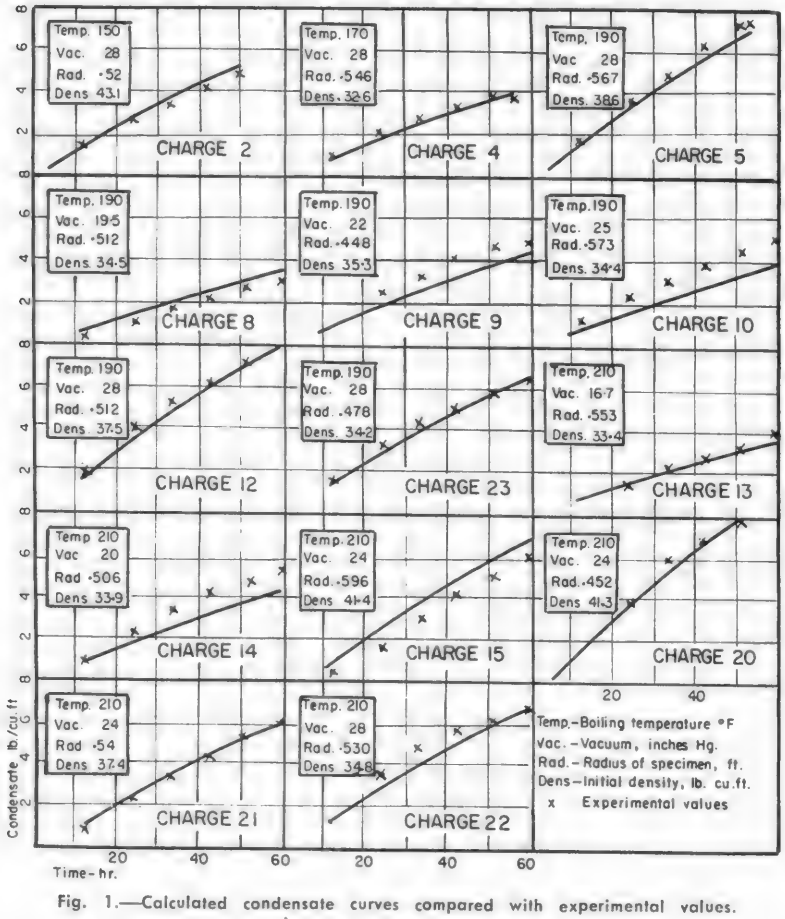


Fig. 1.—Calculated condensate curves compared with experimental values.

The formula for the amount of moisture removed per cubic foot from the experiments, as calculated by successive approximation is (equation 1):

$$C = \frac{(D-23)\ \sin\ (T - \quad)}{2.31\ rp\ .25\ \cot\ \frac{\quad}{\quad}}$$

Where C — pounds condensate per cu. ft.

r — average radius — feet

D — density or weight per cu. ft. — pounds

T — duration of boiling — hours.

d — one-third of delay reaching final boiling temperature — hours.

p — absolute pressure at top of retort — in. Hg. or 30 minus vacuum corrected to sea level.

t — bath temperature deg. F. sine and cotan are expressed as degrees.

A comparison of the condensate calculated by this equation with the actual condensate collected from each of the 14 logs is shown in Fig. 1. The calculated condensates per cubic foot appear as curves while the actual amounts are marked by crosses. Experimental errors may account for the few discrepancies which are evident and protracted rain may also have been the cause of erratic behavior since it may be presumed that it would be concentrated near the surface where it would boil off more readily than interior moisture.

## Discussion of Results

It is probable that additional experiments will make it necessary to modify equation (1). Publication of the formula seems justified, however, because it presents a mathematical relation whose accuracy other experimenters may have an opportunity of testing.

In order to use the equation without the necessity of making difficult calculations, Figs. 2 and 3 are useful. Each

figure combines the effect of two variables into a multiplying factor.

The equation may be written:—

$$C = \frac{1}{{}_{p}.25 \cot \frac{t - 130}{1.8}} \cdot \frac{\sin (T - d)}{2.31\ r} \cdot (D - 23)$$

Fig. 3 represents the first part of this equation

$$\frac{1}{{}_{p}.25 \cot \frac{t - 130}{1.8}}$$

and from it a multiplying factor is obtained which corresponds to any temperature and vacuum (p = absolute pressure in. Hg. or 30 — vacuum in. Hg.). For instance the multiplying factor is 0.80 when the temperature is 210° F. and the vacuum is 27.6 inches, while its value at 190° F. and 19 inches vacuum is 0.40. This indicates that, when all other conditions such as time, radius, and moisture content are constant, twice as much water is boiled from wood at 210° F. and 27.6 inches vacuum as at 190° F. and 19 inches.

The second part, $\frac{\text{sine } (T - d)}{2.31\ r}$ is the time and size factor, and its value for various times and radii is shown graphically in Fig. 2. Its value after 70 hours' boiling is 0.90 when the radius is .450 ft. and 0.68 when the radius is .600 ft.

The third part $(D - 23)$ represents the amount of water in one cubic foot of wood. It is the difference between the actual initial density in pounds per cubic foot, D, and an average oven-dry weight of 23 lb. per cubic foot.

To illustrate the graphic method of employing this equation, Charge 20 may be taken as an example:—

Initial weight = 425 lb.
Radius = .452 ft.
Volume = 10.3 cu. ft.
Bath temperature — t = 210° F.
Vacuum = 24 inches Hg.

One third of delay reaching temperature = 4 hours. The value of $\frac{1}{{}_{p}.25 \cot \frac{t - 130}{1.8}}$ for 24 inches vacuum and 210° F. obtained from Fig. 3 is approximately 0.63. The value of $\frac{\text{sine } (T - d)}{2.31\ r}$ is found from Fig. 2 to be .79 for a log of .452 ft. radius boiled for 60 hours less d (4 hours) = 56 hours. The density $D = \frac{425}{10.3}$ = 41.3 lb./cu. ft. The equation then becomes $0.63 \times .79 \times (41.3 - 23)$ = 9.10 lb. per cu. ft. which corresponds with the weight calculated by the equation.

It is probable that length of the material introduces an additional factor which is not included in this analysis. It is suggested that, pending further experimentation, this equation and these graphs be applied only to material 16 feet long.

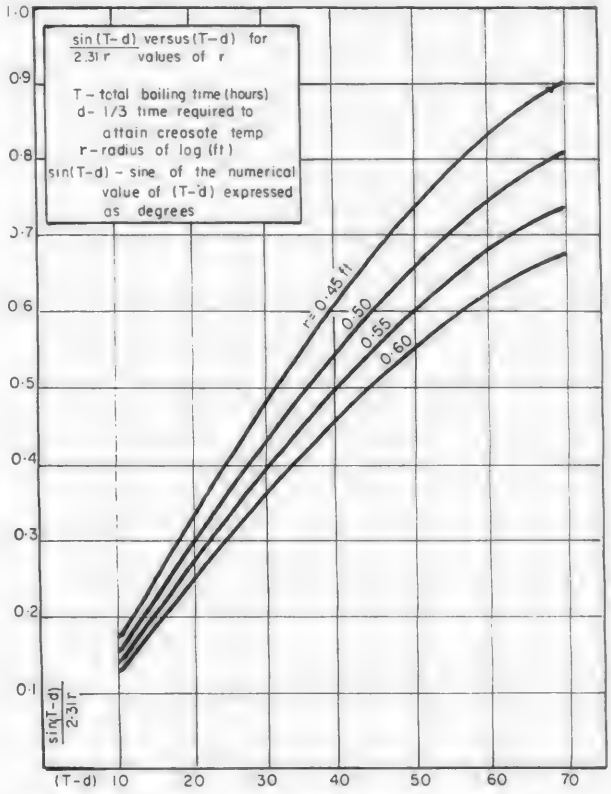


Fig. 2.—Values of second part of formula for various times and radii.

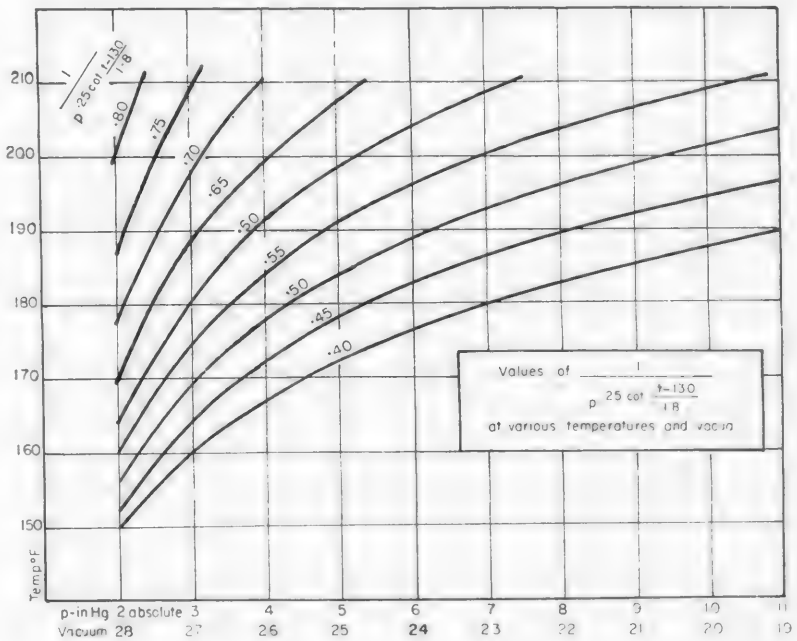


Fig. 3.—Values of first part of formula at various temperatures and vacua.

### Observations

1. According to Fig. 2, when other factors are equal, the amount of water evaporated per cubic foot becomes less as the radius increases. It will be found, however, that the amount of water per lineal foot, or total condensate from a log, increases with the radius.

2. The time factor sine (T — d) becomes a maximum of 1 when T — d = 90 and decreases as T — d becomes greater than 90. However, these experiments ran for only 70 hours and the equation is not applicable for a longer period.

3. The significance of the equation becomes evident from the following examples. Consider four logs weighing 40 lb. per cu. ft., two of them measuring 0.45 ft. radius and two measuring 0.60 ft. radius. One of each radius is boiled at 210° F. with 28-inch vacuum and the other two are boiled at 190° F. with 24-inch vacuum. If the weight of wood substance in a cubic foot is 23 pounds, the initial moisture content is $\frac{(40 - 23)}{23} 100 =$ 74 per cent. The following data demonstrate the effect which size, bath temperature, and vacuum have on the average moisture content after 70 hours boiling.

| Radius Ft. | Bath Temperature °F. | Vacuum Inches Hg. | Final Moisture Content Per cent |
|---|---|---|---|
| 0.45 | 210 | 28 | 18 |
| 0.60 | 210 | 28 | 32 |
| 0.45 | 190 | 24 | 40 |
| 0.60 | 190 | 24 | 48 |

4. One part of the equation (D — 23) is the difference between the weight of one cubic foot of unseasoned wood, D, and the average weight of this volume after oven drying, and it therefore represents the moisture content in pounds.

5. The discrepancy between actual condensate and calculated condensate is comparatively large for charges 8, 10, 14 and 15 and may indicate that there have been experimental errors or that an additional factor such as heat conductivity must be included in the equation. Nevertheless, the equation does provide a behavior guide for the conduct of future experiment

# Chemical Effects of High Energy Irradiation of Wood[1]

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**Reviews studies to date on high energy irradiation of wood components to induce chemical changes. Experimental work on irradiation of cellulose, dextran, lignin, and sawdust is discussed. This recently developed technique is expected to greatly influence the scope of chemical utilization of forest products.**

INDUCING CHEMICAL CHANGES by high energy irradiation is a recently developed technique which may exert a profound influence on the scope of the chemical utilization of forest products. The practical application of this technique is limited at the present time by the prohibitive expense of the construction of an atomic pile or an electron accelerator. However, this appears to be a present condition which may be eliminated in the near future by the development of processes for the disposal of waste radioisotopes. It is anticipated that solution of the increasingly pressing problem of waste radioisotopes may at the same time provide a source of irradiation dosages.

### High Energy Irradiation of Wood Components

It is well known that the exposure of high polymeric materials to massive doses of high energy irradiation produces extensive molecular changes. Whether these changes will involve depolymerization or cross-linking is at present difficult to predict. The major chemical constituents of wood—cellulose, hemicellulose, and lignin—are polymers present in varying degrees of polymerization and containing different units in the polymers as well. Irradiation of the chemical constituents of wood may be expected to produce profound chemical changes.

The technique of high energy radiation is relatively new. High energy radiations which have been used to produce organic molecular changes are X-rays, gamma rays and beta rays. The gamma rays are produced from radioisotopes. The beta rays are high energy cathode rays (high velocity electrons).

The irradiation dose required to produce appreciable change in polymers is large and is approximately the inverse of the molecular weight of the polymer (1).[2] These large irradiation doses can be readily provided by high energy cathode rays. The material is sealed in polyethylene tubes and exposed to irradiation. Suitable tests for depolymerization or cross-linking are made on the irradiated material.

### Irradiation of Cellulose

Cellulose and cellulosic materials have been the subject of several studies of the effects of irradiation.

Lawton et al (2) found that very finely ground irradiated basswood yielded carbohydrate components which became available to rumen bacteria. Radiation must be between 6.5 and $10^6$ and 1.0 x $10^8$ roentgen. At $10^8$ equivalent roentgen, the digestibility of basswood by the rumen contents was equivalent to hay.

Saeman, Millett, and Lawton (3) found that irradiation with high energy cathode rays causes depolymerization and decomposition of cellulose, the extent of depolymerization depending on the dosage. A dosage of $10^5$ equivalent roentgens has little effect. Large changes occur at irradiation levels in excess of $10^6$ equivalent roentgens. At a dosage of 5 x $10^7$ equivalent roentgens, cellulose is converted to water soluble materials. Irradiation at high dose levels caus[es] a

[1] Presented at meeting of Chemical Utilization Division during FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C.

[2] Numbers in parentheses refer to literature cited.

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reduction in crystallinity, and appears to cause a random depolymerization and decomposition of cellulose, in both the amorphous (easily hydrolyzed) areas and the crystalline (difficultly hydrolyzed) areas. Crystalline cotton linters and purified wood pulp were depolymerized at nearly the same rate. At a dose of $5 \times 10^8$ equivalent roentgens, the cotton linters were converted to water-soluble materials.

The depolymerization of cellulose upon high energy irradiation has also been observed by Lawton, Bueche, and Balwit (4) in their studies on the irradiation of polymers. Polymers such as polyacrylic esters, nylon, and natural rubber became cross-linked on irradiation, while cellulose, polyvinyl chloride, polytetrafluoro ethylene and others become degraded.

Little (5) found that cellulose and its derivatives and collogen, upon irradiation, appear to break down to about the same extent in both the crystalline and non-crystalline parts.

### Irradiation of Dextran

Price, Bellamy, and Lawton (6) exposed Dextran, the 1–6 polymer of alpha-O-glucose, to doses of approximately $10^8$ roentgen equivalents and found that the initial molecular weight of several hundred million was reduced to around 50,000. The degradation was accompanied by an increase in branching, with indications that all the branch points were probably tetrafunctional, with four segments or small chain units attached to each branch unit. These investigators found that the efficiency of irradiation both in branching and breaking was constant in the dosage range of $5 \times 10^6$ to $10^8$ roentgen equivalent. They produced a material of molecular weight in the range clinically useful as a plasma extended with dosages of about $5 \times 10^7$ roentgen equivalents.

Ricketts and Rose (7) using $3 \times 10^5$ roentgen (Cobalt 60), produced degradation on a high molecular branched sample and branching on a linear polymer. Degradation was more extensive in solution and higher for branched specimens. No significant cross linking occurred. The products formed appeared to be very similar to those produced by other means of degradation.

### Irradiation of Lignin

Studies on the irradiation of lignin (2) showed that at $10^8$ equivalent roentgen, the range of optimum digestibility by rumen contents, both lignin and cellulose were degraded. Alteration of in situ lignin was slight and not defined. It was not changed sufficiently in a manner that was detectable by the chemical and bacteriological tests applied to the control and irradiated samples.

### Effects of the Irradiation of Sawdust

Experimental work on the effects of high energy irradiation of sawdust has been carried on by Le Mar F. Remmert and Joseph S. Butts at the Oregon Agricultural Experiment Station at Oregon State College. The object of this unpublished work was to study a method for economic conversion of Douglas-fir sawdust to ruminant feed. Of specific interest was the section of the study pertaining to irradiation of sawdust to render the cellulose more available to ruminant livestock.

It is believed that ruminants normally possess means of digesting certain forms of cellulose or degradation products of cellulose. In the case of wood some pretreatment is necessary to make the polysaccharides available. Moreover, the pretreatment involves more than just hydrolysis of beta-glucosidic linkages in the cellulose. It also may be necessary to break any existing lignin-cellulose bonds and the lateral bonds in the crystalline cellulose.

The experimental work on irradiation of Douglas-fir sawdust revealed that the cellulose of this sawdust can be made available to rumen microorganisms, and thus to the host animal, by irradiation. Exposure to a dosage of $10^7$ reps of gamma-rays rendered sawdust more susceptible to hydrolysis by the rumen fluid enzyme, or enzymes, than non-irradiated sawdust. The small, but reproducible, increased hydrolyzability was measured by determining reducing sugar equivalents before and after incubation. Boiling with 20% NaOH for 1 to 2 hours, greatly magnified the hydrolyzability of the irradiated sawdust. Direct acid hydrolysis of sawdust samples indicated that irradiation at a dosage of $3.2 \times 10^8$ reps with gamma or beta rays destroyed approximately 1/3 of the total carbohydrates. Whereas the glucose equivalent of reducing values was 661 mg./gm. of sawdust in the control (non-irradiated sawdust), it was only 415 mg./gm. of sawdust in the irradiated sample.

Incubation of sawdust samples exposed to $3.2 \times 10^8$ reps with gamma or beta rays with rumen enzyme preparations for 48 hours showed that irradiation caused a marked increase in the amount of carbohydrate made soluble by action of the rumen enzyme or enzymes. Separation of the incubation mixtures into soluble and insoluble portions, followed by acid hydrolysis of each portion, gave almost quantitative recovery. Irradiation resulted in the destruction of approximately 1/3 of the carbohydrates of Douglas-fir sawdust. One-fourth to one-third of the remaining carbohydrates after gamma irradiation, or roughly 16 per cent of the carbohydrates initially present in the sawdust, could be converted to the soluble condition by the rumen enzyme preparation. After beta irradiation about two-thirds could be converted to the soluble condition by the rumen enzyme preparation. As a contrast, only 1 to 3 per cent of the carbohydrates of non-irradiated sawdust could be solubilized by the rumen enzyme preparation.

### Conclusion

The pioneering work reviewed above indicates that high energy irradiation may open up new potentialities for the chemical utilization of wood.

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# Dimensional Stabilization of Wood[1]

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**A study was made of vapor-phase acetylation catalyzed by dimethylformamide, as well as crotonylation, crotylation, phthaloylation, butylation and allylation of wood under various conditions. Antishrink efficiencies close to 100 per cent are reported in some cases. Other properties of treated wood are discussed.**

## Introduction

WOOD IS STILL the most versatile and most used building material, exceeding plastics, light metals, and all of its other competitors combined. Of the major problems confronting the users of lumber, the need for modifying the hygroscopic properties of wood and thereby improving its dimensional stability ranks high on the list of importance (15). Shrinkage is responsible for loss of footage, warping, end and surface checking, end splitting, honey combing, and case hardening. Sticking doors and windows, warping and cracking floors, and loose joints in furniture are common manifestations of this property.

Many methods have been proposed by wood technologists to impart greater stability to the dimensions of wood. All of them, however, may be segregated into four general categories (24):

1. Coating the external or the microscopically visible internal structure with paints or water-repellent chemicals;
2. Depositing bulking agents within the cell-wall structure to obstruct shrinkage;
3. Chemically modifying one or several of the wood components, including blocking or replacing the hydroxyl groups of cellulose and lignin with less polar groups;
4. Forming cross links between the structural units.

Water repellents, though quite effective in stabilizing the dimensions of fabrics, are not very effective in stabilizing those of wood. They reduce the rate of swelling and shrinking, but not to as great an extent as good surface coatings such as aluminum paints, high-pigment paints, and synthetic resin varnishes. This reduction in rates of dimensional changes, however, helps reduce internal strains in the wood which might result in grain raising, warping, and checking. Neither water repellents nor surface coatings alter the final equilibrium dimension changes; they affect only the speeds with which they are attained (5).

The second method for dimensional stabilization of wood outlined above involves keeping the material in a partially or completely swollen state by the bulking action of chemicals deposited within the cell-wall structure. This can be accomplished with water-soluble salts (25), sugars (26), and a pyridine-allyl chloride polymer (11, 12), but with these the wood is always damp at high relative humidities, is subject to leaching with subsequent loss of dimensional stability, and is weaker than the dry wood.

The bulking effect may also be imparted by water-insoluble substances. One method used (30) consists of quantitatively replacing the water in swollen wood by Cellosolve (ethylene glycol monoethyl ether), which can in turn be replaced by water-insoluble substances such as waxes or fatty acids. However, such replacement procedures, although effective, are not easily applicable to large pieces of wood. Another treatment of a similar type uses glycol dicarboxylic acid monoesters (7, 46). More recently, Stamm (28) used carbowaxes in conjunction with water-soluble phenolic resins.

A reduction in equilibrium swelling and shrinking to one-third or one-quarter of the normal changes may be accomplished quite simply by the introduction of water-soluble urea- or phenol-formaldehyde resinoids, followed by the formation of thermosetting resins within the cell-wall structure (6, 17, 24, 32). Since the water-swollen dimensions are not altered by the treatment, the treated wood undergoes a smaller volume change when immersed in water than does a corresponding control. Such a treatment improves most of the mechanical properties of the wood, except toughness, which is reduced.

More recently, a method of acetylating the wood has been employed to cause bulking of wood fibers, thereby imparting dimensional stability (19, 33, 34, 35, 43, 44). This method involves both a replacement of hygroscopic hydroxyl groups by less hygroscopic acetyl groups and a bulking effect due to the introduction of the more bulky acetyl groups in place of the hydroxyls. Increased dimensional stability, however, is attributed to the bulking effect rather than to a reduced hygroscopicity. This acetylation may be done in either the liquid or the vapor phase, the latter being preferred, using acetic anhydride, with pyridine as a combination of catalyst and swelling (or "activating") agent. Zinc chloride has also been used as catalyst.

An example of chemical changes involved in the third general method is the heating of wood at elevated temperatures. Pyrolytic changes in structure may be obtained under various conditions, such as heating at 205° C. in presence of gases (hydrogen, air, oxygen, city gas) (31), or heating beneath the surface of molten salts (sodium and potassium acetate) at about 285° C. (27), or heating to about 170° C. under high pressure ("Staypak") (21), or heating to about 150° C, beneath the surface of a molten metal ("Staybwood") (29, 30, 31). Initially the increased dimensional stability imparted by such heat treatments was attributed to ether cross links, formed by the loss of water of constitution from hydroxyl groups of adjacent cellulose chains (29, 30, 31). This theory has, however, been disproved (22, 38), the stabilizing action being probably due to the breakdown of the more hygroscopic hemicelluloses and the formation of insoluble polymers from the sugars and furfural formed.

In the last group of methods for increasing the dimensional stability of wood, cross links of polystyrene may be produced by the polymerization of

[1] This paper constitutes part of a thesis submitted by D. F. Arseneau in partial fulfillment of the requirements of the degree of D. Sc. in Chemistry, Graduate School, Laval University, May 1955. Financial assistance was given to Mr. Arseneau by the Shell Oil Co. and the Quebec Scientific Research Bureau.

[2] The paper was prepared while Dr. Arseneau was a graduate student at Laval. He is now on the staff of the Dept. of Chemistry, Xavier Junior College, Sydney, N. S., Canada.

vinyl benzene with small amounts of divinyl benzene which yields a polymer with greatly reduced swelling (39). Cross linking also occurs by reacting cellulose (42, 43, 47) or wood (36, 37, 43) with small amounts of formaldehyde vapor. This reaction, however, requires a strong mineral acid at a pH of 1 or lower, thereby resulting also in serious embrittlement. Such a treatment therefore is impractical with wood unless some less acidic catalyst can be found. A reduction of two-thirds in swelling and shrinking results when as little as 2 to 4 per cent formaldehyde is introduced into the wood by this method. Equal stability can be attained in acetylation only by the introduction of 18 to 20 per cent acetyl.

The present investigation was undertaken to search out improved methods of the third group, i.e., methods of imparting stability to the dimensions of wood by chemical means and to study the mechanism by which this stabilization is effected.

# Part I. Acetylation

### Theoretical and Historical

Acetylation is one of the many types of reactions in which the hydroxyl groups of cellulose and lignin may participate. When acetic anhydride is used, the reaction proceeds in the following way:

$$ROH + (CH_3CO)_2O \rightarrow CH_3COOR + CH_3COOH$$

where R may represent a lignin residue, a polysaccharide chain (as cellulose or hemicelluloses), or any other organic radical.

This reaction requires a catalyst, usually a strong mineral acid. In addition, if R is a large radical, a second agent must be present to swell, and thereby expose the most intimate structure to the acetylating agent. This swelling agent is sometimes referred to as the activating agent. Commercially, acetic acid is often used to swell or activate the cellulose molecule, and a small quantity of sulfuric acid in acetic anhydride is later added.

Literature mentions many activators, or combinations thereof, other than acetic acid (3, 14, 45). Acid catalysts other than acetic acid have also been used, including zinc chloride (13, 16, 18) and boron trifluoride (8). Basic catalysts have also proved acceptable for the acetylation of cellulose, including urea (45), and potassium and sodium acetates (2, 3, 16).

Certain organic bases such as pyridine also catalyze the reaction between hydroxyl groups and acetic anhydride. Hess (9) found that cellulose could be acetylated to the triester stage without any apparent degradation. He replaced the water in water-swollen cellulose with pyridine and then treated the pyridine-catalyzed material with a solution of pyridine and acetic anhydride. Starch too can be acetylated with pyridine and acetic anhydride without breakdown in structure (20). Further studies were made by Hiller (10) who determined the kinetics of acetylations using acetic acid. Others also have studied acetylation of cellulose (40, 41).

In such base-catalyzed acetylations, acetic acid cannot be used as activating agent because of salt formation. Fortunately, however, pyridine exhibits a powerful swelling ability towards wood, causing about 25 per cent more swelling than water. Since cellulose does not swell appreciably in pyridine, while isolated lignin does, it may be concluded that it is the lignin in wood which responds to the pyridine. Thus pyridine may serve as both catalyst and swelling agent. This has been the basis of extensive work carried out by Stamm et al (33, 34, 35, 43, 44).

Dimethylformamide has been used as an accelerating agent in coupling reactions (4) and in condensations (23), as well as activator and solvent in acetylations (45).

Bender et al (1) have accomplished acetylation of cellulose and wood in a liquid-phase procedure using dimethylformamide as catalyst and swelling agent.

In the present work, some results of vapor-phase acetylations both in presence of pyridine and dimethylformamide are reported.

### Experimental

**Preparation of samples:** Three sizes of wooden blocks were used in the course of experimentation: 1) cubes measuring 1½ inch, 2) cylinders or wafers measuring 1-1½ inch longitudinally and 1½ inch in diameter, and 3) blocks measuring 2 inches by ½ inch by 1/3 inch, the largest dimension being in the direction of the fibers. All pieces for a given series of experiments were cut from the same bolt and numbered consecutively as cut. Samples were carefully finished and rough sides sanded. Their dry weights and dry dimensions were determined after being dried in an oven at 110° C. for 24 hours and cooled in a desiccator. The weights of all samples were recorded to the nearest thousandth of a gram. The dimensions were taken using a micrometer caliper and recorded to the nearest thousandth of an inch. The reproducibility of such measurements is indicated by the fact that for a series of 50 measurements on a wafer 1.469 inch in diameter, the maximum deviation from the mean was 0.002 inch.

**Soak Testings:** The effect of any treatment upon dimensional changes of wood was determined by soaking the treated and control samples in distilled water at 24° C. for 24 hours. Surface water was removed with a towel and the samples weighed and measured. As with Stamm et al (44), the effectiveness of a treatment in preventing swelling was expressed as the Antishrink Efficiency (A.E.) which is defined as shown below.

**Humidity Studies:** Untreated controls and samples treated to various degrees of substitution were subjected to atmospheres of controlled humidities. After a two- or three-week stay at one humidity, the samples were weighed and measured, and then moved into the chamber of next higher relative humidity (R.H.). The constant R.H.'s were obtained by placing saturated salt solutions (zinc sulfate, sodium chlorate, magnesium acetate, potassium nitrite, calcium chloride, potassium acetate, and lithium chloride) in a desiccator and keeping them at room temperature which varied between 23 and 26° C. during these studies. The R.H.'s of the chambers were periodically checked.

**Acetylations:** Acetylations were carried out in a glass treating chamber provided with an efficient condensation system, according to the general procedure described by Stamm et al (44).

A) Cubes of white birch sapwood (*Betula papyrifera*, Marsh) were soaked for six hours in pyridine. After being air-dried for one hour, the samples were placed in the treating chamber and subjected to vapors of a solution of 70 per cent acetic anhydride and 30 per cent pyridine. Treating times in this chamber were varied from 4 to 48 hours, yielding samples with acetyl contents varying from 1 to 19 per cent. For each set of samples treated, another sample underwent all

$$\text{A.E.} = \frac{\text{Per cent swelling of control} - \text{Per cent swelling of treated sample}}{\text{Per cent swelling of control}} \times 100$$

Reduction in Water Absorptivity (R.W.A.) is similarly defined:

$$\text{R.W.A.} = \frac{\text{Per cent increase in weight of control} - \text{Per cent increase in weight of treated sample}}{\text{Per cent increase in weight of control}} \times 100$$

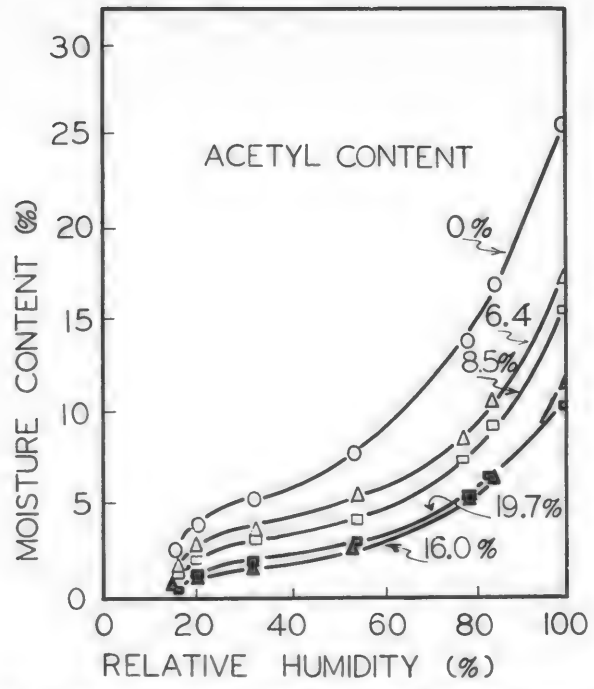


Fig. 1.—Relation between relative humidity and moisture content of balsam fir cubes of various acetyl contents.

treatments except the actual acetylation, and served as a control in subsequent tests. After treatment, the samples were dried at 110° C. for 24 hours, cooled in a desiccator, weighed and measured. Their acetyl content was expressed as the percentage gain in weight over the original oven-dry weight. The samples were then soak-tested for antishrink efficiencies.

B) Wafers of balsam fir (*Abies balsamea* (L) Mill.) were acetylated in a manner similar to the above, yielding samples of acetyl contents from 5 to 19 per cent. Some of these were soak-tested, but the majority of them were used for relative humidity tests.

C) Cubes of balsam fir were acetylated using dimethylformamide as a catalyst and swelling agent instead of pyridine. The procedure was identical to above, except that dimethylformamide replaced the pyridine at all stages of the process.

D) Attempts were made to acetylate wood using the acetic anhydride-boron trifluoride complex (obtained by passing boron trifluoride into acetic anhydride) according to Evans (8), but in all cases highly degraded woods resulted.

## Results

Table 1 shows the relationship between treating time, acetyl content (A.C.) and antishrink efficiency (A.E.) of balsam fir cubes acetylated with dimethylformamide as a catalyst and swelling agent. Although the number of samples acetylated were too few (seven) to give a picture of statistical value, it appears that both A.C.'s and A.E.'s increase with increasing treating time. It is also noticed that A.E.'s generally increase with A.C.'s.

For pyridine-catalyzed acetylation, the relationships between A.C.'s and A.E.'s were determined and were found to duplicate the findings of Stamm et al (33, 34, 35, 43, 44).

Fig. 1, illustrating the relationship between the relative humidity and the moisture content on the basis of the oven-dry weight of the treated balsam fir cubes, shows that the acetylated samples exhibit reduced hygroscopicity, and that this reduction increases with increased A.C.

Fig. 2, relating moisture content of the acetylated wood to the per cent tangential swell, shows that the relationship is linear, i.e. for each addition of moisture the samples swell accordingly.

Fig. 3 shows what happens dimensionally to samples of acetylated wood

Table 1.—RELATIONSHIP BETWEEN TREATING TIME, ACETYL CONTENT, AND ANTISHRINK EFFICIENCY OF BALSAM FIR CUBES ACETYLATED USING DIMETHYLFORMAMIDE AS CATALYST AND SWELLING AGENT (VAPOR-PHASE)

| Treating time, hours | Acetyl content % | Antishrink efficiency % |
|---|---|---|
| 2 | 7.3 | 41.7 |
| 4 | 5.9 | 48.6 |
| 7 | 11.0 | 65.6 |
| 14 | 11.5 | 51.1 |
| 17 | 13.9 | 68.8 |
| 23 | 13.7 | 51.9 |
| 24 | 14.0 | 63.4 |

Table 2.—REDUCTION IN WATER ABSORPTIVITY OF ACETYLATED BALSAM FIR CUBES AT VARIOUS RELATIVE HUMIDITIES

| Acetyl content, % | 6.4 | 8.5 | 10.1 | 16.0 | 19.7 |
|---|---|---|---|---|---|
| Relative humidity, % | Reduction in water absorptivity, % | | | | |
| 15 | 26.0 | 35.9 | 34.6 | 65.5 | 57.0 |
| 20 | 26.9 | 35.7 | 34.2 | 60.2 | 54.6 |
| 32.2 | 29.5 | 26.8 | 35.8 | 64.3 | 54.4 |
| 54 | 28.2 | 37.3 | 34.6 | 58.1 | 51.6 |
| 79 | 33.4 | 39.4 | 36.4 | 55.7 | 51.4 |
| 84 | 34.8 | 40.0 | 37.4 | 54.9 | 52.8 |

when they are subjected to atmospheres of various relative humidities .

As mentioned above, Fig. 1 shows that acetylated wood exhibits reduced hygroscopicity. Not only does this reduction depend upon the A.C., but also upon the relative humidity. Table 2, compiled from the data used to plot Fig. 1, shows the reduction in water absorptivity at different humidities. It shows that treated samples possessing A.C.'s of less than 16 per cent display decreasing hygroscopicity with increasing relative humidity, while samples with A.C.'s of 16 per cent or greater have increasing hygroscopicity with increasing relative humidity.

## Discussion

For the acetylation of wood, the effect of variables and the interrelationships of the many properties of the acetylated wood have been well established by Stamm et al (33, 34, 35, 43, 44). Their proposed mechanism of stabilization as imparted by acetylation has, however, some aspects which may be extended.

The problem of reduced water absorptivity, or reduced hygroscopicity, seems to be more complicated than first believed. Table 2 shows that hygroscopicity not only varies with A.C., but also with the relative humidity. Woods with A.C.'s below 16 per cent show lessening hygroscopicity with increasing humidities, whereas woods with A.C.'s greater than 16 per cent show increasing hygrscopicity with increasing humidities.

In the work of Stamm et al, graphs relating acetyl content to anti-shrink efficiency experience a pronounced change in slope in the range of 16 per cent acetyl content. It would appear that once A.C. surpasses 16 per cent, a different type of reaction sets in. Perhaps the acetylation up to this point is merely on the surfaces of the fibrils, whereas above 16 per cent the acetylation proceeds in the interior.

Previous workers have shown that the bulking effect explains the limited swelling experienced by a piece of acetylated wood at its maximum, water-soaked dimension. The reduced hygroscopicity imparted by the acetyl groups was claimed to exert only an insignificant effect. However, wood more often experiences dimensional changes resulting from variations in rel-

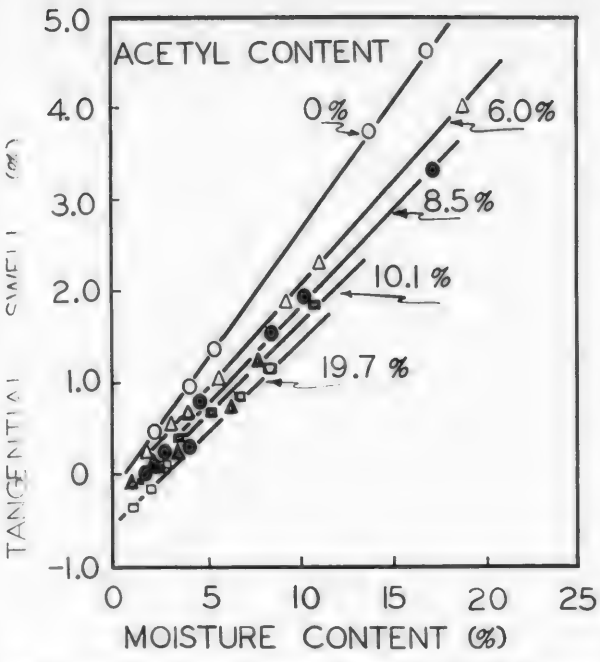


Fig. 2.—Relationship between moisture content and per cent tangential swell of balsam fir cubes of various acetyl contents.

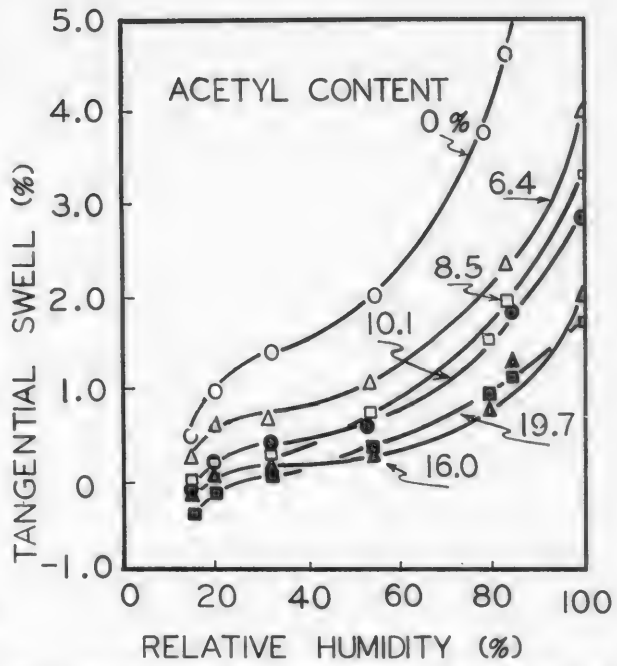


Fig. 3.—Relation between the relative humidity and tangential swell of balsam fir cubes of various acetyl contents.

humidity. A consideration of stabilization under these conditions is therefore desirable.

Fig. 2 shows that tangential dimensions respond to changes in moisture content, and Fig. 1 in turn shows that the moisture content varies with the relative humidity, this variation depending upon the hygroscopicity of the specimen. Indirectly, then, the swell experienced by a piece of wood *does* depend upon its hygroscopicity.

Fig. 3 showing what happens dimensionally to acetylated wood during humid periods, makes it clear that the swelling of acetylated wood approximately parallels the swelling of untreated wood. Thus bulking influences swelling over the entire course of the swelling, not only at the final stage as observed in butylation (see Part IV, to be published in a subsequent issue).

The dimensional stability of acetylated wood when subjected to changes in relative humidity therefore seems to depend upon a combined effect of bulking and decreased hygroscopicity, both of which result from the introduction of the acetyl groups.

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# Effect of Tension Wood in a Leaning Eastern Cottonwood[1, 2]

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**The effects of tension wood on certain physical properties of a leaning cottonwood tree were studied. The objective was to determine the distribution of gelatinous fibers, the amount of longitudinal shrinkage of specimens from various positions in the tree, specific gravity of longitudinal shrinkage samples, and the correlation between specific gravity, longitudinal shrinkage, and number of gelatinous fibers.**

## Introduction

BOTTOMLAND HARDWOODS are becoming increasingly important in the wood economy in many parts of the country, particularly in the Midwest. Of the bottomland species, cottonwood is noted for its rapid growth and high yield as well as having the additional advantage of being able to grow on parts of farm lands unsuitble for agriculture due to stream flooding and poor drainage.

A recent survey of the wood using industries[3] in 26 counties in southern Iowa showed a total of 72 million bd.ft. of lumber used annually (13)[4]. Of this total, cottonwood accounted for 17 million bd.ft. of which 97.6 per cent was cut from Iowa forests. The survey also showed that of all the industries using cottonwood, at least 85 per cent had difficulties in connection with seasoning and fabrication. Many of the problems associated with the marketing and manufacturing of cottonwood are related to the presence of excessive amounts of tension wood.

The improvement in the marketing possibilities for Midwest bottomland hardwoods depends in part upon a more complete understanding of tension wood and its effects. To determine the characteristics of tension wood it is necessary to become familiar with its properties both macroscopic and microscopic.

The terms stimulus wood, abnormal wood, and reaction wood have been used to refer to tissues formed in the leaning stems and branches of angiosperms and gymnosperms (4). The reaction wood of angiosperms is more commonly known as tension wood, *bois de tension,* Zugholz, Weissholz, and white wood (10). The term tension wood will be used throughout the present report to refer to the reaction wood of angiosperms. Tension wood derives its name from its position on the upper side of leaning members where the tissues are considered to be under a tension stress. The wood from this region is physically, chemically, and anatomically different from normal wood (5).

The most important visual diagnostic characteristic of tension wood is projecting fibers which give rough sawn lumber a fuzzy, wooly appearance. Pillow (9) noted that mahogany boards containing tension wood left a rough, fuzzy surface after being ripped with a special saw that usually left a smooth surface.

Gelatinous fibers occur abundantly in the upper or tension side of leaning hardwoods and therefore can be used to identify this tissue. Although stem eccentricity might be indicative of tension wood, this is not always the case. Akins and Baudendistel (1) noted in cottonwood that some gelatinous fibers were found on the shorter radii of an eccentric log. Kaeiser (6) and Kaeiser and Pillow (7) determined the frequency of gelatinous fibers at various heights in leaning cottonwood trees along six radii of each cross-sectional disk and from the same growth ring. At breast height the gelatinous fibers were found in greater concentrations on the upper side. Great variation occurred at the middle and top heights, with the greater concentrations being frequently found in the lower and lateral sides. The amount of gelatinous fibers were found to increase with increasing lean of the tree. The gelatinous fibers can occur singly, in isolated groups, or in broad bands. Marra (8) states that the one constant feature of gelatinous fibers is that they are never present in the last few rows of cells in the latewood.

The cell walls of gelatinous fibers have a thick inner cellulose layer, much thicker than found in normal wood fibers. The gelatinous layers are commonly buckled or folded into the cell lumen resembling a distinct layer which has lead some authors to refer to it as a tertiary layer or tertiary wall (2, 3). Wardrop and Dadswell (12) and Pillow (9) observed the thickness of the gelatinous layer to vary greatly from the normal fiber ranging from those with a well defined lumen to those in which the lumen is almost completely occluded.

The most serious difficulty with tension wood is encountered during the seasoning process. Release of the internal stresses in tension wood results in bowing, crooking, and twisting. These deformations result from differences in longitudinal shrinkage between normal wood and tension wood. It has been shown by many authors that longitudinal shrinkage of tension wood is excessive. Microscopic analysis has also revealed that the greater the number of gelatinous fibers the greater is the longitudinal shrinkage.

The objective of this investigation was to study the effects of tension wood on certain physical properties of eastern cottonwood *(Populus deltoides* Bartr.) The objective can be broken down as follows: 1) to determine microscopically the distribution of gelatinous fibers in a leaning cottonwood tree; 2) to determine the amount of longitudinal shrinkage of specimens from various positions in the tree from the green condition down to various moisture contents; 3) to determine specific gravity of all longitudinal shrinkage samples; and 4) to determine the

[1] Entered in the 1956 Wood and Wood Products Award competition sponsored by Vance Publishing Co., Chicago. The paper is based on a thesis submitted in partial fulfillment of the requirements for the M. S. degree at Iowa State College.

[2] Journal Paper No. J-2945 of the Iowa Agricultural Experiment Station, Ames, Iowa.

[3] Excluding home use and construction.

[4] Numbers in parentheses refer to literature cited.

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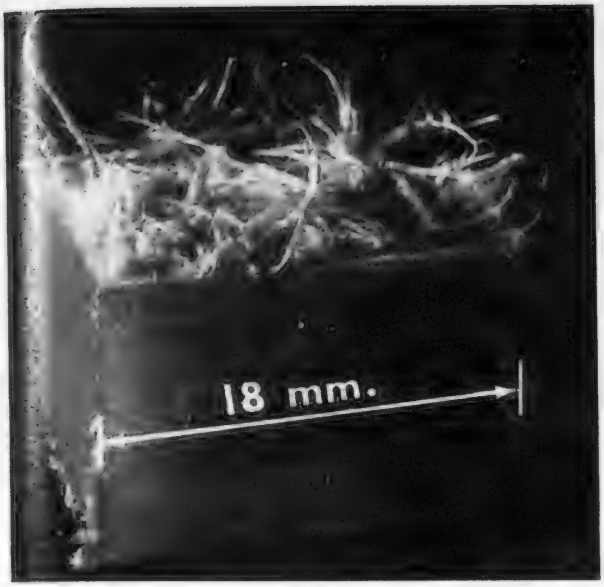


Fig. 1.—One of the quartered sections, approximately 18 mm in length, used for microtome sectioning. A large mass of projecting fibers can be seen on this tension wood section.

Fig. 2.—Longitudinal shrinkage measuring device capable of measuring to the nearest 0.001 inch.

Table 1.—AVERAGE* AND RANGE OF SPECIFIC GRAVITY FOR THE UPPER AND LOWER SIDES AS RELATED TO HEIGHT

| Height Above Ground in Feet | Upper Side | Lower Side | Grand Average |
|---|---|---|---|
| 1 | 0.368 (0.326–0.398) | 0.367 (0.343–0.386) | 0.368 |
| 11 | 0.370 (0.321–0.393) | 0.372 (0.357–0.390) | 0.371 |
| 21 | 0.369 (0.338–0.398) | 0.378 (0.347–0.395) | 0.373 |
| 31 | 0.381 (0.349–0.405) | 0.386 (0.362–0.411) | 0.383 |
| 39 | 0.393 (0.359–0.420) | 0.403 (0.377–0.425) | 0.398 |
| Grand Average | 0.376 | 0.381 | |

*Averages computed from the five samples for each of four boards from the upper and lower sides of the lean.

correlation between specific gravity, longitudinal shrinkage, and number of gelatinous fibers.

## Methods of Study

**Selection of tree and specimens:** The eastern cottonwood tree selected for study had the following characteristics: diameter breast high, 22.2 inches; total height, 95 feet; age, 42 years; and a lean of 13 per cent (7 degrees 34 minutes) from the vertical. Since tension wood is predominantly found on the upper side of leaning trees, the upper side was clearly marked before the tree was felled. After felling, the tree was bucked into four logs, labeled A, B, C, and D, each 10 feet in length except the D log which was 8 feet. What constituted the upper side of the lean was clearly marked on each log and will be referred to as the upper side.

The logs were immediately sawn (essentially flat sawn) into 1⅛ inch boards in a manner in which four boards were obtained from each of the lateral sides and five or six boards from the upper and lower side of the lean. A section 1 foot in length was cut from the butt end of every board as well as the top end of all boards from the D log. After the sections were cut and coded, they were immediately immersed in water to prevent moisture loss and shrinkage.

From each one-foot section, five pieces approximately one-inch in width were cut to obtain straight grain samples. If a defective sample was found, another sample was cut adjacent to it. The samples were then immersed in water and taken to the laboratory for study. A total of 380 such samples were cut from seventy-six 1-foot sections representing all sides of the tree at heights of 1, 11, 21, 31, and 39 feet.

**Laboratory procedure:** The samples were trimmed to a length of 7¾ inches. A ¾-inch section was then cut and quartered from the butt end of each sample. These quartered sections (Fig. 1) were boiled in distilled water until they sank and then preserved in 70 per cent alcohol for anatomical studies. The remaining samples, now 7 inches in length, were used for longitudinal shrinkage measurements.

The specific gravity for each sample was computed on the green volume, oven-dry weight basis. The green volume was determined by the water immersion method for which weight determinations were made to 0.01 gram.

After computing green volume, the green length was measured to the nearest 0.001 inch with a special longitudinal measuring device as illustrated in Fig. 2. Following these measurements the samples were put into a conditioning chamber and seasoned from the saturated state to that of 22, 12, and 8 per cent moisture content. At each of these stages, the samples were removed from the chamber and immediately remeasured. After conditioning and measuring at the 8 per cent level, the samples were oven-dried, weighed, and measured again.

The microscopic analysis was restricted to the four outside boards on the upper and lower side of the leaning tree. From each of the 200 jars containing the quartered sections preserved in 70 per cent alcohol, one of the quarters was randomly selected for microtome sectioning. Transverse sections approximately 14 microns in thickness were cut on a sliding microtome. The sections were stained with chloriodide of zinc and examined immediately under a microscope. Examination immediately is necessary due to the temporary nature of this reagent.

Two transverse sections from each sample were analyzed with a compound microscope equipped with a movable stage, at a magnification of 100x. To estimate the comparative number of gelatinous fibers in each transverse section, a frequency distribution system similar to that described by Terrell (11) and Kaeiser (6) was used. The frequency class (F) of the gelatinous fibers was first determined by general observation as being occasional, scattered, abundant, or solid, and assigned the numerical values of 5, 20, 50, and 70 respectively. For the distribution value (D) the portion of the total cross sectional area occupied by the gelatinous fibers was determined as .05, .1, .2, .3, .4, through .9. An estimate of the comparative number of gelatinous fibers (N) was obtained by multiplying the frequency value (F) by the distribution value (D) for each cross section examined.

By slowly traversing the entire section under the microscope, the frequency class was easily determined. The method used for determining the distribution class is worthy of note. The occular of the microscope was equipped with cross hairs which enabled dividing the field of view into quadrants. Starting at one corner of the section and slowly traversing the entire area, it was possible to determine by count the total number of quadrants (T) in the entire cross section. By the same token, it was possible to determine the number of quadrants occupied by gelatinous fibers (G). The

quotient of these numbers gave the decimal value for the distribution.

Each microtome section was also examined microscopically at magnifications of 430x and 630x for additional diagnostic characteristics of the gelatinous fibers. A few photomicrographs were made of both temporary slides stained with chloriodide of zinc and permanent slides stained with safranin-fast green.

## Results and Discussion

The most obvious visible characteristic of tension wood is the abundance of projecting fibers giving the wood a peculiar fuzzy or wooly appearance (Fig. 1). This particular feature was observed on all boards from the upper side of the tree and was found to decrease somewhat with height. There were no projecting fibers visible on the boards from the lower side at heights of 1, 11, and 21 feet but at heights of 31 and 39 feet some projecting fibers were present.

Cross sectional disks were cut from the butt end of the first three logs and both the butt and top ends of the fourth log. In no instance was growth eccentricity noted on the upper or tension side of the tree. At the top height of 39 feet, stem eccentricity was noted on the lower side and in this instance some gelatinous fibers were also found.

When the longitudinal shrinkage samples were measured at the 8 per cent moisture content level, eight samples were noted to contain areas of collapse. Six of the eight samples were from the upper side of the lean and did contain large numbers of gelatinous fibers.

**Specific gravity:** The average specific gravity (green volume, oven-dry weight basis) shows a distinct difference between the sides as can be seen in Fig. 3. The upper or tension wood side shows the lowest specific gravity

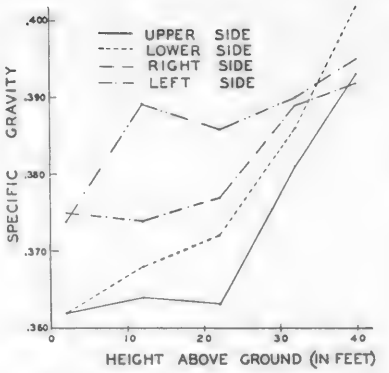


Fig. 3.—Relation of specific gravity (based on green volume and oven-dry weight) in a leaning cottonwood tree to height and position in the cross section. The points are averages of five samples in each of three to five boards.

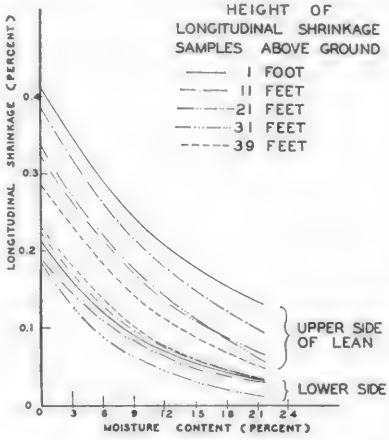


Fig. 4.—Amount of longitudinal shrinkage from the green dimension to dimensions at various moisture contents as related to height in a leaning cottonwood tree.

while the left side has the highest specific gravity. Tables 1, 2, and 3 show the average specific gravity at various heights and positions in the tree using only the four outside boards. An analysis of variance computed for specific gravity as related to heights, sides, and positions showed no significance for the interaction between height and sides. This is indicated in Table 1 and Fig. 3 where it is noted that, except for the first height, the difference in specific gravity between the sides was essentially the same.

The significance of the interaction between heights and boards is apparent in Table 2, which shows that the difference in specific gravity between boards was somewhat less as height increased.

Table 3 indicates the significance of the interaction between sides and boards. The difference in specific gravity between the upper and lower sides increases from the bark toward the pith.

Specific gravity increases from the pith outward and from the base of the tree to the top. This trend of increasing specific gravity with increasing height (Tables 1 and 2) is most difficult to explain. It is somewhat fallacious to compare the specific gravity of the fourth board in from the bark at a height of 1 foot with the specific gravity of the fourth board in from the bark at a height of 40 feet. In doing so, two important considerations, position in the tree and age, are overlooked. Had it been possible to classify these data by age of the wood in the specimens and by position, there would likely have been less increase in specific gravity with height.

**Longitudinal shrinkage:** At all heights examined, longitudinal shrinkage was greater on the upper or tension wood side of the lean than on the lower side (Fig. 4). It is also evident in Fig. 4 that the greatest longitudinal shrinkage for the upper side occurred at the base of the tree and decreased with increasing height. The least amount of longitudinal shrinkage for the upper side occurred at the greatest height in the tree, but is still greater than the largest shrinkage value found for the lower side of the lean. The longitudinal shrinkage values on the lower side showed no relation to height.

An analysis of variance was computed to determine whether height in the tree, side of the lean, distance from bark, or combinations of those factors had any effect on the longitudinal shrinkage from green to oven dry. Again only the four outside boards from the upper and lower sides of the lean were used. The analysis showed significant results with every factor considered. The reasons for the high degree of significance in the statistical analysis is readily apparent in Tables 4, 5, and 6.

The relation of longitudinal shrinkage to height for the upper and lower

**Table 2.—AVERAGE* AND RANGE OF SPECIFIC GRAVITY FOR BOARD POSITIONS AS RELATED TO HEIGHT**

| Height Above Ground in Feet | BOARD POSITION† 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.369 | (0.361–0.373) | 0.382 | (0.365–0.389) | 0.371 | (0.358–0.398) | 0.351 | (0.326–0.376) |
| 11 | 0.379 | (0.367–0.393) | 0.383 | (0.368–0.390) | 0.371 | (0.358–0.388) | 0.351 | (0.321–0.373) |
| 21 | 0.386 | (0.374–0.398) | 0.387 | (0.379–0.398) | 0.367 | (0.350–0.385) | 0.353 | (0.338–0.386) |
| 31 | 0.399 | (0.386–0.409) | 0.395 | (0.381–0.411) | 0.378 | (0.374–0.385) | 0.363 | (0.349–3.372) |
| 39 | 0.399 | (0.391–0.404) | 0.401 | (0.391–0.417) | 0.404 | (0.391–0.425) | 0.387 | (0.359–0.410) |
| Grand Average | 0.386 | | 0.389 | | 0.378 | | 0.361 | |

*Averages computed from ten samples for the two corresponding boards from upper and lower sides.
†Board number 1 is nearest the bark.

**Table 3.—AVERAGE* AND RANGE OF SPECIFIC GRAVITY FOR UPPER AND LOWER SIDES AS RELATED TO BOARD POSITION**

| | BOARD POSITION† 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Upper Side | 0.387 | (0.361–0.405) | 0.389 | (0.379–0.405) | 0.376 | (0.350–0.420) | 0.353 | (0.321–0.403 |
| Lower Side | 0.385 | (0.363–0.409) | 0.390 | (0.365–0.417) | 0.381 | (0.358–0.425) | 0.369 | (0.343–0.410) |

*Averages computed from five samples from each board at five different heights.
†Board number 1 is nearest the bark.

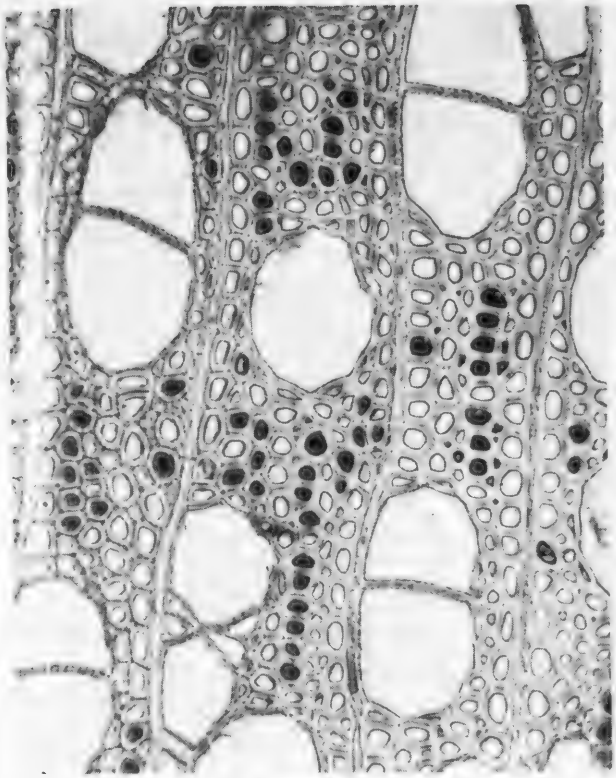

Fig. 5.—Frequency classification of gelatinous fibers considered as scattered. Magnification 190x.

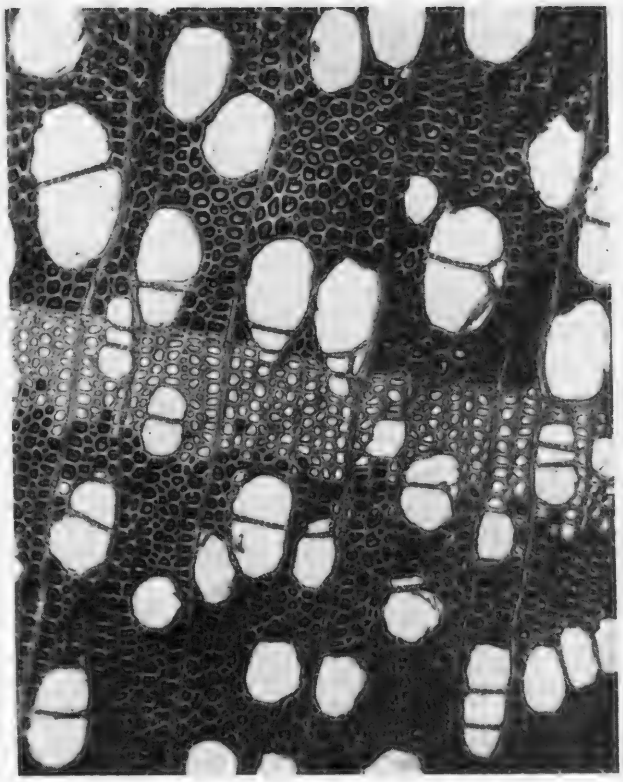

Fig. 6.—Frequency classification of gelatinous fibers considered as solid. This section had the highest comparative number of gelatinous fibers recorded, with .9 of its cross-sectional area being occupied by solid groups. The solid group terminates sharply in the latter part of a growth increment. Magnification 96x.

sides can be seen in Table 4 where it is noted that the grand average for each height indicates a distinct decrease in the amount of longitudinal shrinkage with increase of height up to the 31-foot level, where a slight increase is noted. Table 4 also shows a difference in the amount of longitudinal shrinkage between the two sides.

The significance of the interaction between heights and boards is apparent in Table 5 where it can be seen that the difference in longitudinal shrinkage between the boards decreased with increasing height.

Table 6 indicates the significance of the interaction between sides and boards where it is noted that the difference in longitudinal shrinkage between the upper and lower sides increased from the first board to the third board in from the bark and then decreased sharply in the fourth board. The boards from the lower side illustrate the usual condition for a normal tree in that the boards closest to the pith possess the greatest longitudinal shrinkage. Although board number 4 on the upper side was closest to the pith, it did not exhibit the greatest longitudinal shrinkage as might be expected from its position in the tree. Similar relationships were also found for the longitudinal shrinkage at the three other moisture contents considered.

**Table 4.—AVERAGE* AND RANGE OF LONGITUDINAL SHRINKAGE IN PER CENT (FROM GREEN TO OVEN-DRY) FOR THE UPPER AND LOWER SIDES AS RELATED TO HEIGHT**

| Height Above Ground in Feet | Upper Side | | Lower Side | | Grand Average |
|---|---|---|---|---|---|
| 1 | 0.410 | (0.196–0.933) | 0.212 | (0.168–0.279) | 0.311 |
| 11 | 0.387 | (0.224–0.575) | 0.222 | (0.140–0.335) | 0.305 |
| 21 | 0.323 | (0.153–0.642) | 0.188 | (0.070–0.335) | 0.256 |
| 31 | 0.337 | (0.209–0.614) | 0.182 | (0.112–0.265) | 0.259 |
| 39 | 0.283 | (0.140–0.475) | 0.229 | (0.126–0.544) | 0.256 |
| Grand Average | 0.348 | | 0.207 | | |

*Averages computed from the five samples for each of four boards from the upper and lower sides of the lean.

**Table 5.—AVERAGE* AND RANGE OF LONGITUDINAL SHRINKAGE IN PER CENT (FROM GREEN TO OVEN-DRY) FOR BOARD POSITION AS RELATED TO HEIGHT**

| Height Above Ground in Feet | BOARD POSITION† 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.232 | (0.168–0.306) | 0.334 | (0.182–0.543) | 0.425 | (0.196–0.933) | 0.252 | (0.196–0.335) |
| 11 | 0.261 | (0.140–0.575) | 0.404 | (0.223–0.574) | 0.280 | (0.154–0.436) | 0.278 | (0.182–0.364) |
| 21 | 0.211 | (0.126–0.502) | 0.305 | (0.070–0.642) | 0.238 | (0.168–0.348) | 0.268 | (0.195–0.351) |
| 31 | 0.278 | (0.154–0.614) | 0.275 | (0.154–0.447) | 0.246 | (0.154–0.377) | 0.240 | (0.112–0.363) |
| 39 | 0.147 | (0.126–0.182) | 0.264 | (0.168–0.377) | 0.274 | (0.168–0.474) | 0.340 | (0.209–0.544) |
| Grand Average | 0.225 | | 0.317 | | 0.292 | | 0.276 | |

*Averages computed from ten samples for the two corresponding board from upper and lower sides.
†Board number 1 is nearest the bark.

**Table 6.—AVERAGE* AND RANGE OF LONGITUDINAL SHRINKAGE IN PER CENT (FROM GREEN TO OVEN-DRY) FOR UPPER AND LOWER SIDES AS RELATED TO BOARD POSITION**

| | BOARD POSITION† 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| Upper Side | 0.296 | (0.140–0.614) | 0.407 | (0.252–0.642) | 0.382 | (0.209–0.933) | 0.306 | (0.195–0.475) |
| Lower Side | 0.155 | (0.126–0.224) | 0.226 | (0.070–0.377) | 0.202 | (0.154–0.378) | 0.245 | (0.112–0.544) |

*Averages computed from five samples of each board at five different heights.
†Board number 1 is nearest the bark.

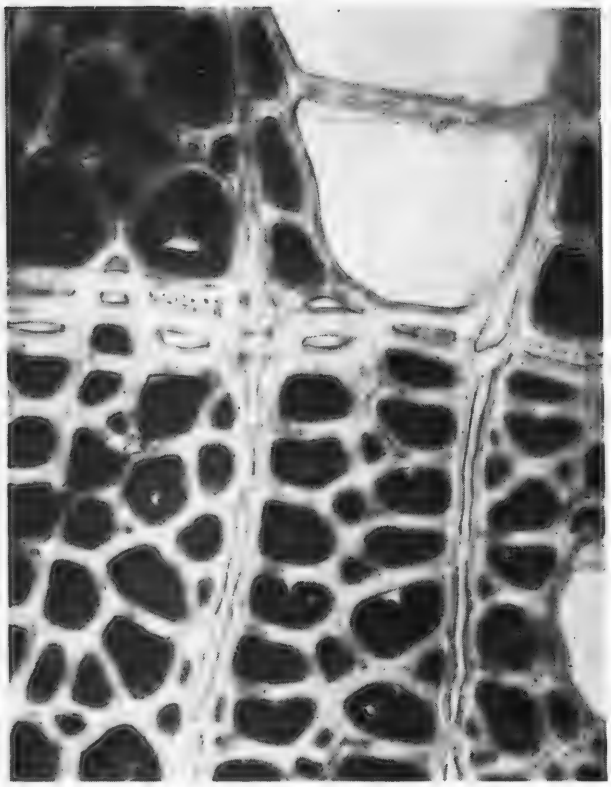

Fig. 7.—A solid group of gelatinous fibers, with the gelatinous layer in a buckled or folded state, occurring throughout the entire latewood. Magnification 495x.

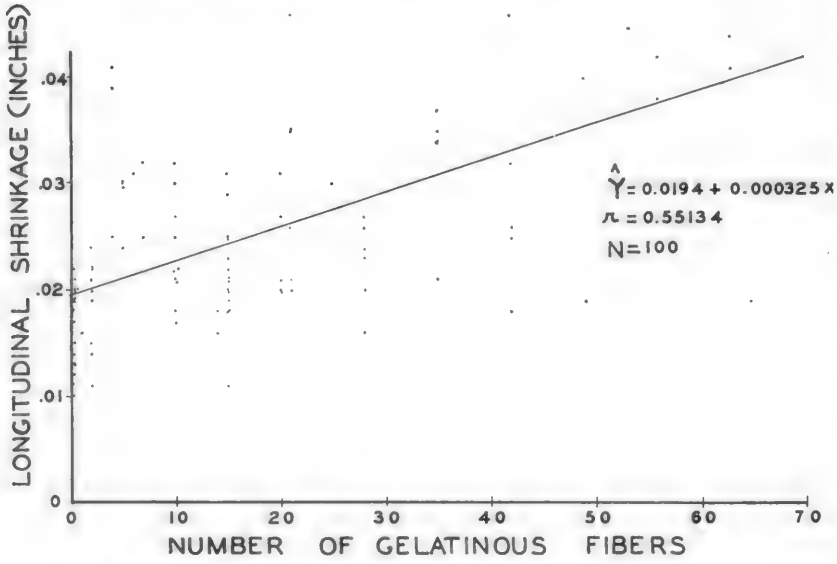


Fig. 8.—Relation of longitudinal shrinkage on comparative number of gelatinous fibers for a leaning cottonwood tree.

Table 7.—COMPARATIVE NUMBER OF GELATINOUS FIBERS AS RELATED TO THE UPPER AND LOWER SIDES, BOARD POSITION, AND HEIGHT IN A LEANING COTTONWOOD TREE. RESULTS ARE AVERAGES OF FIVE SAMPLES IN EACH BOARD

| | BOARD POSITION* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | | |
| Height in Feet | Upper | Lower | Upper | Lower | Upper | Lower | Upper | Lower | Average |
| 1 | 0.15 | 0 | 13.2 | 0 | 17.0 | 0 | 9.10 | 0 | 4.93 |
| 11 | 31.40 | 0 | 37.2 | 0.85 | 16.0 | 0.05 | 6.15 | 0 | 11.46 |
| 21 | 28.80 | 0 | 29.6 | 0 | 12.2 | 0 | 13.45 | 0 | 10.50 |
| 31 | 36.6 | 0.10 | 16.8 | 0.35 | 13.4 | 0.25 | 19.20 | 9.8 | 12.06 |
| 39 | 0.20 | 0.20 | 1.0 | 0.45 | 13.25 | 2.45 | 23.00 | 6.5 | 5.88 |
| Average | 19.43 | 0.06 | 19.56 | 0.33 | 14.37 | 0.55 | 14.18 | 3.26 | |

*Board number 1 is nearest the bark.

**Microscopic characteristics:** In total, 200 microtome sections were cut, stained, and analyzed. Two of the four gelatinous fiber frequency classes, scattered and solid groups, are illustrated in Figs. 5 and 6. The staining reagent, chloriodide of zinc, swells the gelatinous layer and turns it to a deep purple or almost black color, while the remainder of the fiber wall and the walls of normal wood fibers are not swelled and turn yellow in color. The gelatinous layer was so large that in most instances it completely occluded the lumen as seen in Fig. 7. With this folded appearance, it is hard to imagine that this layer could have been strongly attached to the other layers of the secondary wall.

Another peculiar characteristic of the gelatinous fiber is the seemingly arbitrary location in a given cross section. They can be scattered (Fig. 5) or occur in solid bands (Fig. 6). They can start or stop suddenly anywhere within the annual ring. Gelatinous fibers may be absent in one part of an annual ring and present in other parts of the same increment. They may be completely absent in one annual ring and found in solid masses in the next increment. For the most part when they do occur in solid bands, they will stop before reaching the end of an annual ring (Fig. 6). In other instances, the gelatinous fibers occurred in all but the last one or two rows of latewood cells (Fig. 7). In still other less numerous instances, the gelatinous fibers would occupy the entire latewood area as seen along the right edge of Fig. 7. The thickness of the gelatinous layer varies considerably, from normal fiber wall thickness to layers which completely occlude the lumen.

Frequency determinations of gelatinous fibers for 200 sections from the four outside boards of the upper and lower side of the lean show without a doubt that the upper side contained the greatest number of gelatinous fibers (Table 7). In the first three logs studied (A, B, and C) only three sections from the lower side contained gelatinous fibers and their number was small. At the two top heights (D and DT), gelatinous fibers were found quite frequently on the lower side but still not to the extent found on the upper side.

**Factors affecting longitudinal shrinkage:** To determine the individual and joint effects of specific gravity and frequency of gelatinous fibers on longitudinal shrinkage, a multiple regression problem was set up. The absence of a correlation between specific gravity and longitudinal shrinkage and between specific gravity and comparative number of gelatinous fibers made

a multiple regression unnecessary. It is likely, however, that if age and position had been held constant for like samples at various heights in the tree specific gravity would have been more closely related to longitudinal shrinkage.

A significant correlation was found between frequency of gelatinous fibers and longitudinal shrinkage. The greater the concentration of gelatinous fibers, the higher the longitudinal shrinkage. Had all four of the quartered sections from each longitudinal shrinkage sample been sectioned, instead of only one, a greater correlation would no doubt have been obtained. A scatter-diagram was made with the 100 longitudinal shrinkage samples from the upper side of the lean representing the ordinate and their respective comparative number of gelatinous fibers representing the abscissa. A regression line was fitted to the points as shown in Fig. 8. Roughly 30.4 per cent of the variation in longitudinal shrinkage was linearly associated with the comparative number of gelatinous fibers. On the average, it can be assumed from these data that for every increase of one in the comparative number of gelatinous fibers, there will be a corresponding increase of 0.003 inch in longitudinal shrinkage.

Figs. 9 and 10 show the frequency distribution pattern of the longitudinal shrinkage for the upper and lower side respectively. It is readily apparent that the samples from the upper side of this leaning cottonwood possessed the greatest longitudinal shrinkage.

For merchantable hardwood trees now being cut, it seems evident that marking the upper side of the tree would prove of great advantage during the sawing operation. With the upper side marked, the logs could be sawed at right angles to the lean, obtaining high quality lumber from the lower side. The boards from the upper side would contain a more uniform distribution of gelatinous fibers resulting in more uniform longitudinal shrinkage and less warping. When the boards are cut parallel to the direction of lean it seems logical to expect that those boards would possess the greatest longitudinal shrinkage differential and consequently would warp more upon seasoning. This condition was evident in specimens which bowed or crooked during the seasoning process. In every instance, tension wood possessing the greater longitudinal shrinkage was found on the concave side of the bow or crook.

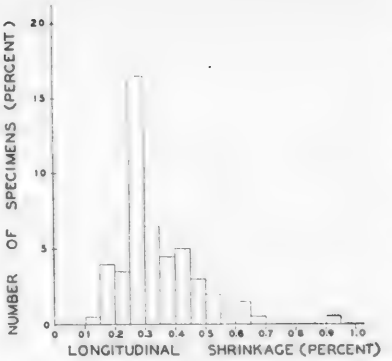


**Fig. 9.—Frequency distribution of longitudinal shrinkage values for the 100 samples from the upper side of a leaning cottonwood tree.**

Variation in longitudinal shrinkage in normal wood fibers has been largely attributed to the orientation of the fibrils in the thick middle layer of the secondary wall. Since the fibrils of this layer in normal wood are nearly parallel to the long axis of the cell, longitudinal shrinkage is negligible. In gelatinous fibers, a considerable part of the inner and middle layer of the cell wall seems to be replaced by the gelatinous layer in which the fibril orientation is even more nearly parallel to the longitudinal axis of the cell. This should further reduce the amount of longitudinal shrinkage. Since this, however, is not the case, an explanation is suggested for the greater longitudinal shrinkage of tension wood. That is, the gelatinous layer, which is observed as being frequently pulled away from the rest of the secondary wall and therefore is loosely attached, no longer controls longitudinal shrinkage. If this is the case, the outer layer

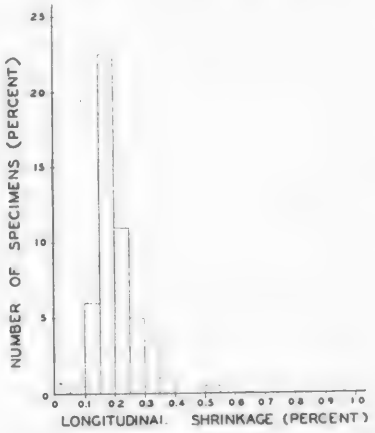


**Fig. 10.—Frequency distribution of longitudinal shrinkage values for the 100 samples from the lower side of a leaning cottonwood tree.**

of the secondary wall and the primary wall must control the amount of longitudinal shrinkage. The fibril orientation in the outer layer of the secondary wall is at a much greater angle from the vertical and excessive longitudinal shrinkage would be expected.

Information from this study, when added to the findings of other workers, leaves no doubt that gelatinous fibers are related to longitudinal shrinkage and are found for the most part on the upper side of leaning angiosperms. It should be remembered that the information gained from this study is the result of a detailed study of only one tree. Additional trees would have added much to this study but a more intensive study is possible when only one tree is used.

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# Timber Design and Construction Handbook

Edited by RALPH H. GLOSS

Senior Engineer, Timber Engineering Co., Washington, D. C.

A WEALTH OF DETAILED INFORMATION for the designer of timber structures is available in this new book. Not only is this the most complete compilation on the subject to date, but also much of the information has never before been published. The list of 25 authors is a veritable "Who's Who" in the field of timber engineering.

The great volume of information in the book is well organized for accessibility to the user. Two chapters on basic properties logically precede the details of their application to design. The design sections are concise and clearly labeled, permitting the reader to find quickly what he wants, while adequate references guide him to a more detailed discussion where needed. Reprints of detailed design standards follow. A table of contents, a glossary, and an index are provided.

Of particular interest is the second part, the so-called "experience section," of which little has ever appeared before in print. A host of practical details are found here. As stated in the preface, this section is "more the result of experimentation and experience of individual designers and builders, than of ordained results flowing inevitably from theory." And yet, perusal of this section reveals ample evidence of the thorough grounding in theory to which the experience is related.

An interesting question is developed in the foreword. Suppose that wood were a newly discovered product of the research laboratory. "This new material is available in vast quantities. The supply renews itself so the product will always be available. It is strongly competitive in cost. It will not shatter when struck; its resilience permits it to absorb shocks that would rupture or break other material. It has fine natural insulating qualities. It can be produced in large sizes; it can readily be worked into items of exceptional delicacy. It stands up ruggedly under abuse . . . It is relatively light in weight, yet possessed of great strength." While such a thought has been expressed before, consideration of it in this light refreshes one's appreciation of the structural properties of this age-old material.

The "experience section" on design is followed by three chapters of design standards. The latter includes much reprinted material which might well have been brought in by reference, since it is subject to frequent revision. The preface to chapter 13 suggests that users of the book may need to obtain separate copies of such standards as "National Design Specification" to be assured of the latest revisions. If this is advisable, the need for reprinting such a standard in full seems questionable.

While the title states that this is a handbook of design and construction, design is given by far the greatest emphasis. Fabrication, assembly, erection, and maintenance are all compressed into a single chapter; surely these subjects deserve fuller treatment, and the authors' experience could add greatly to them. At the same time, much of value will be found in this chapter. Observations that careful fabrication is the key to efficient assembly, and that in-place repairs require ingenuity and careful planning, testify to the authors' competence in these fields as well as in design.

The treatment of allowable stresses and allowable loads follows the general lumber industry policy of assuming seasoned lumber and "normal loading," rather than the more conservative basis of unseasoned lumber and long-time loading. While mention of the more conservative basis is made, it is inconspicuous and could be easily overlooked by the user of the book. For example, the chapter on exterior structures makes no mention that allowable stresses or loads may be lower than those for lumber "continuously dry as in most covered structures." No basis is clearly shown for reducing tabulated working stresses for conditions of exterior or other severe exposure.

Some sections, such as those on trusses or on heavy timber construction, are complete and detailed, while others on pole framing or on diaphragms are quite sketchy. This is not so much an oversight on the part of the authors as a reflection of the present inadequate state of knowledge in those areas. It points up needs for further research in timber construction.

One cannot fail to be impressed by the great amount of work that has gone into the compilation of this handbook. Timber engineers will find it a valuable addition to their libraries. Timber Engineering Company is to be congratulated on a big job well done.

LYMAN W. WOOD, Engineer
*Forest Products Laboratory*

# A Practical Approach to the Prevention of Decay and Termites in Building Construction

PANEL DISCUSSION

**Proper construction practices, preservative treatments, termite shields, and other means of preventing decay and termite damage in buildings are discussed. It is pointed out that modern design and uses of lumber have increased chances for such damage. The wood industry must adopt preventive measures if wood is to maintain its competitive position in the construction field.**

THE FOLLOWING DISCUSSION is part of a panel presentation by a building contractor, commercial termite control operator, an advocate of treated wood, and a representative of a treating company. The second part of the discussion will be published in the July issue.

The discussion was presented at Session II, Wood Preservation, during the FPRS Tenth National Meeting, June 4–7, 1956, in Asheville, N. C. The session was conducted by the Wood Preservation Division under the chairmanship of Ira Hatfield, Wood Treating Chemicals Co., St. Louis, Mo. Dr. Ralph Lindgren, U. S. Forest Products Laboratory, Madison, Wis., was panel moderator and the discussion was recorded by Dr. J. B. Huffman, School of Forestry, University of Florida, Gainesville, Fla.

## Industrial and Residential Construction

W. L. G. MAC KENZIE

President, Fiske–Carter Construction Co., Spartanburg, S. C.

In industrial construction the gradual acceptance of concrete floors for ground floors has partially eliminated the problem of termites in this location. However, there is still much resistance to the rigidity of concrete on the part of employees who have to stand continuously. Some advance has been made in the use of emulsified asphalt surfacing to provide floors with more resilience, but many industrial plants, especially in the textile field, still feel it necessary to provide wood floor surfaces on ground floors for certain parts of the process.

This requirement has resulted in numerous expedients, the best of which is the use of pressure-treated lumber subfloors laid in coal tar derivatives mixed with sand (called tarred sand) over either tarred rock or concrete laid in contact with the earth. Over the treated subfloor, a hardwood untreated finish flooring usually forms the actual wearing surface. The writer's experience with this type of floor extends over a period of over 30 years. Floors at least that old have been taken up and found in good condition without serious rot or termite infestation in areas where the subsoil in contact with the tarred rock or concrete has been dry, although much of the fiber stress of the treated lumber is gone. Where periodic or continual moisture is present in the subsoil in contact with the tarred rock or concrete, some rot has been found in the treated lumber and untreated top floor. Few termite infestations have been found in this type of floor.

With the advent of air-conditioning or air-changing in textile plants where high humidity is a continuous factor, and where in order to maintain constant heat and humidity, windowless plants have been built or converted, the problem of fungus infection has increased enormously. This is further complicated by systems of humidifying requiring a constant pressure in the manufacturing areas. These humidifying pressure systems seem to cause penetration of the high humidity completely through the wood section in these areas. All of the prerequisites for rapid fungus deterioration are present, i.e., heat, moisture, and limited air circulation. Under such conditions it has been our experience that treatments of lumber should be increased to greater than normal retentions of impregnated chemicals, and initial installations should be absolutely dry.

While high humidities have been required in certain parts of cotton textile manufacturing for a long time, it is noted that the mills formerly were not pressure humidified and large windows with excessive air leakage around sash kept the moisture content of the lumber in these areas down. It is only since the widespread use of roof insulation (with vapor barriers) and windowless manufacturing rooms that this fungus problem has increased markedly.

### Termite Control

The subterranean termite problems in manufacturing plants and commercial structures can be controlled by careful design.

1. Eliminate continuous hollow masonry walls by termite cut-offs.
2. Eliminate wood (especially untreated wood) in contact with or close proximity to earth.
3. Install termite shields over piers in seldom-visited underfloor areas.
4. Use soil poisoning.

In industrial and commercial construction, the increase in use of structural steel instead of timbers, due to scarcity and high price of quality grades of timber, has eliminated some of the problems formerly encountered. The versatility of wood plank floors in multiple story industrial plants has been demonstrated over the years and even with the problems it entails, no satisfactory substitute has appeared for all uses.

This versatility of lumber is demonstrated by the following list of qualifications:

1. Ability to stand overloading repeatedly.
2. Ability to stand repeated wetting and drying.
3. Ease of attachment of shafting, conduit, machinery, etc.
4. Resiliency.
5. Elasticity.
6. Ability to expand and contract within known limits.

The scarcity of dry heavy plank and timbers with good structural strength has been a factor in causing some engineers to experiment with other materials such as precast concrete, Insulrock, Tectum, Gypsum, etc. None have the versatility of wood. As the cost of satisfactory lumber properly treated increases, it more nearly approaches the price of such substitutes.

### Residential Construction

In residential construction where wood still forms a major portion of the materials of construction, it has

become a matter of good practice for all wood structural members of the floor close to the ground to be pressure treated. Many builders feel this should also extend to all studding and storm sheathing (if wood is used for sheathing).

FHA and other lending agencies have made the use of metal termite shields mandatory. However, the quality of workmanship of installation of shields varies greatly and so also does its efficacy. I have seen 45° 2-inch bends successfully navigated by termite tubes. Periodic inspection of crawl spaces in unexcavated areas is absolutely necessary.

Soil poisoning should be used during construction to eliminate termite colonies. Here again the painstaking care with which the work is carried out means the difference between success and failure. However, several companies which have pioneered in this line prefer to keep secret the chemical composition of their product rather than make it available to all at a reasonable cost. I am also impressed with the newer tube systems whereby soil poisoning can be renewed at periodic intervals by pressure.

The increasingly popular slab-on-earth ranch type of home construction makes it necessary that proper subdrainage be arranged; that absolute termite cut-offs be very carefully installed in all masonry walls (especially important in hollow wall construction); and that soil poisoning be done throughout entire soil under house.

For homes where the more conventional floor on piers with only partial basements are constructed, increased crawl depths should be provided. The popularity of forced warm air heating and air conditioning makes it increasingly difficult to crawl around under the house and inspect for rot and termites. If it is made too difficult, this inspection will be slighted, resulting in unknown damage occurring.

The prevalence of hollow masonry residential wall construction with weep holes at ground level presents a new problem from termite infestation from the exterior if, through error, some weep holes are covered up. All building contractors, of necessity, should have a thorough working knowledge of the cause of rot and the habits of subterranean termites, as the care with which precautions against them are taken determines results to a large extent. This care must come from the contractors' organizations, for it requires more attention than can be obtained from cursory inspections by architects or lending agency representatives.

In buildings with wood floors above a crawl space, insufficient attention is given to the following problems:

1. Sufficient ventilation.
2. Provisions to prevent prolonged dampness in areas under floors.
3. Measures to prevent termites from crawling up inside hollow masonry walls.
4. Initial ground poisoning.
5. Enough room for proper inspection under floors.
6. Cleaning up of all scraps of wood under and around building at completion, with special care to see that no blocks are incorporated in backfill around walls.
7. Dampproofing crawl space.

Many times builders contract to build a structure where the plans do not provide precautions against decay and termites that are sufficient to ensure a durable structure. The contractor is then faced with these choices:

1. He can advise the owner of the deficient plans and arouse the ire of the architect or engineer.
2. He can build the structure as designed and when the defects in planning eventually show up he will be accused of failing in his duty by the owner.

Many times the owner simply will not spend enough to build in the proper provisions to prevent decay or termite damage, and instructs the contractor to build without them. If this occurs, the builder should, by letter, acknowledge the instructions, call attention to what he thinks will happen, and then build as instructed.

Repeated complaints and demonstrations that methods of treating and drying lumber injure inherent strength and elasticity indicate that this problem warrants the further attention of wood preservers.

### Discussion

*John Reno* (Pacific Lumber Co.): To begin with, I want to state I have no axe to grind for or against treated lumber of any type, soil poisoning or termite shields. My company is a large lumber manufacturer and our interest is the proper protection of lumber in buildings in a completely adequate manner at the lowest possible cost. We must be careful not to recommend pressure-treated lumber where it is not needed; we might price ourselves out of the market.

This comment is with regard to Mr. Mackenzie's report on the industrial building with an untreated wood floor over a treated sub-floor over treated sand and gravel, and his statement that in 30 years very little decay took place in either floor. This is a good record and is probably due to the fact that the dew point in the floor was always in the treated portion and never on either surface of the untreated portion.

Probably he could get the same good results with future floors with untreated wood and sand throughout if he placed a proper vapor barrier on the ground under the wood. I think his choice could be based merely on the cost of each type of protection. Soil covers have proven their value in residential buildings—why not in industrial buildings?

Mr. Mackenzie stated that with the advent of air conditioning in the textile mills which had pressure-treated subfloors and untreated hardwood floors, the problem of fungus infection increased enormously. Why are not true air conditioning systems installed to eliminate moisture and thus prevent the decay of wood?

*Mr. Mackenzie*: It is not practical because high humidities are required to keep textile fibers from breaking. Monie Hudson might give us some details on this matter.

*Monie S. Hudson* (Consultant): In certain areas of the plant, the wood is wet enough to decay because the textile fibers are kept moist by an atomizing spray system. If measured with a psychrometer, the relative humidity will be found to be about 85 per cent, but with respect to the wood, the relative humidity is over 100 per cent. This is because the spray disperses the water droplets as an aerosol and these are attracted to the wood, where the water is absorbed and produces a much higher moisture content than is indicated by the psychrometer measurement.

*R. J. Kowal* (Southeastern Forest Experiment Station): A comment on secrecy of soil poisoning formulations: There may have been secrecy in the past but not much now; the composition of most of the standard soil poisons is known. Regarding shields, I have seen and tried many different types of termite shields and I feel that when properly installed they give satisfactory service. In some cases good shields do fail when termite populations are high and this is the reason why periodic inspection of the shield system becomes highly important. One big trouble is that home-owners will not make the effort or do not know that they should inspect the shield system.

*Mr. Reno:* I have seen cases in Washington, D. C. where soil covers are used on the ground under houses to prevent the rising of moisture. Recent investigations indicate that these soil covers will create conditions too wet for termites to exist. If this is

true, treated lumber may not be necessary.

*Mr. Kowal:* I do not have much faith in the protection soil covers would give from termite attack. Some of our most destructive termite species thrive and even enjoy very wet soil.

*Craig C. Campbell* (Wynnewood Products Co.): Mr. Mackenzie, what is the cost per square foot for the industrial floor described in your paper?

*Mr. Mackenzie:* The cost is relatively high. I cannot quote an exact figure but it will be several times that of a concrete floor. Of course, we install it only in those areas where operators must stand as these floors are less tiring than those of concrete.

*Mr. Campbell:* Do you know of any cases where synthetic particle board products have been preservative-treated prior to formation of the board?

*Mr. Mackenzie:* I do not know of any particle boards that have been so treated.

*Ray Osborne* (American Wood Preservers Institute): Would it be feasible or can designers avoid the use of pressure-treated wood in textile mill construction by using proper construction procedures?

*Mr. Mackenzie:* No, I do not believe so. However, all building materials have some drawbacks. Concrete slabs need insulation against moisture, they need reinforcements which in time rust, expand, and split the slab to open it up. Creosote is dark and is not paintable. Salt-treated lumber we find should have higher retentions when used under the worst hazard conditions. Proper design will help but there are still places where well-treated products are the only answer.

*Noel Kittell* (Joslyn Manufacturing & Supply Co.): What reason can be given as to the cause of the reduction of strength in the wood fibers?

*Mr. Mackenzie:* The reduction is probably caused by the heat or steaming to which the wood was subjected during the treating process.

# What is the Pest Control Industry Doing to Keep Wood in the Picture?

MYRON W. SMITH[1]

Hill–Smith Systems, Memphis, Tenn.

As pest control operators we are daily making inspections on residences and commercial structures for termites and other wood insects. This is in effect a "post-mortem" view. We find problems due to improper planning, improper use of materials, poor building, and in other cases, poor building housekeeping. In commercial structures we find untreated wood posts set on concrete platforms at grade level. We find exposed loading docks of untreated lumber. We find soil over concrete bases of the posts, and in many cases termites traveling directly into the structure. We find wooden grade windows of untreated lumber damaged by both termites and decay. We find poorly installed termite shields, in many cases incorrectly designed, improperly installed, and in general ineffective. We find residences with the sills and first floor joists of treated material but untreated subfloor, studs, hardwood floor, and trim, with termite activity frequently prevalent in the untreated members of the building. We find untreated sill plates laid on top of hollow concrete block and stiff legs or braces used during construction allowed to remain after construction is finished, providing ready access for termites to the main structure from the soil. We find unexcavated areas with no ventilation. Some of these features or imperfections could be overcome by proper design and supervision during construction. In other cases, materials used are wholly inadequate for the purpose intended.

The pest control industry is largely concerned with the correction or prevention of termite and powder post beetle infestation, rather than decay. As an industry, we are equipped to control most of the insect pests which attack finished lumber. While our work is primarily residential work, we come in contact to a limited degree with warehouse problems. The common complaints from the public go along these lines:

1. "Our architect told us we would have no trouble from termites if we installed termite shields during construction. Now we have termites and the building is only seven years old."

2. "All of our floor joists and sills are pressure-treated lumber. Our lumber dealer told us this would prevent termites."

3. "We spent several hundred dollars extra money for redwood siding because we were told termites would not attack."

4. "The builder told us that if we had a solid poured concrete foundation instead of hollow block we would not be bothered by termites."

5. "We used all kiln-dried lumber because we were told the insects were killed in the drying process."

6. "Our builder told us that since we were building on a concrete slab we could forget termites."

These are just some of the usual phrases we hear from our termite inspectors in the course of business. It is apparent that for some reason the public is poorly informed and also that some misrepresentation or misunderstanding has taken place.

As a commercial termite control operator, almost daily I hear the expression "Why doesn't somebody do something about preventing termites before all this damage occurs." A number of individuals, firms, and agencies as well as groups such as architects, lumbermen, and termite control operators are each doing something. There has been little coordination of these efforts. I am not criticizing the architects, pressure treaters, the builders, or even the termite control operators for their various individual methods. Each industry and group will naturally have a different slant on the best way to eliminate or control subterranean termites or powder-post beetles in any given structure. Too frequently all of us are prone to discount the other's opinion or experience. We know that inroads have been made into the building construction industry by the use of alternates for lumber. Failure of lumber to perform under a given set of conditions has been largely responsible for this. Wood, however, is still the most versatile building material available today and properly used will perform very satisfactorily and economically.

## Termite Control

The Wood Destroying Organisms Committee of the National Pest Control Association has been vitally interested for many years. In 1938 this group adopted a basic set of rules to control a termite infestation already established. These were:

1. Reconstruction, replacement, and repair.
2. Soil treating.
3. Foundation treating.

In 1950 work was undertaken by this committee to set up an approved reference procedure for subterranean termite control. The analysis of the committee's work revealed five probable factors to be considered to get a true picture of the problem of termite control on a national scale. These were:

1. Building construction.
2. Incidents of infestation.
3. Behavior of chemicals in the soil.
4. Economic problems of the customer.
5. Quite possibly the species of subterranean termites involved.

[1] Representing the National Pest Control Association.

From this analysis it can be indicated that the termite control operators are taking into account the design of a building as well as the economics involved.

Up until that time, little thought had been given to the prevention of termite infestation by the commercial termite control operator. However, in a few isolated cases, some of the operators were undertaking some preventive measures. As early as 1939 we did soil treating before slabs were poured. This was done to protect the cork insulation of walk-in coolers in dairies and groceries. However, most of this early work was done in a field of residential construction and it was under one of two plans.

Under the first plan the aggressive termite control operator, in dealing with a builder who was aware of the termite control problem, sold the builder on the idea of pretreating. In this case the cost of this pretreatment was paid for by the builder and in most cases no extra allowance was made by the mortgage agency for this work. It is a case of a conscientious builder taking additional steps to provide a better piece of merchandise for the prospective home buyer. The usual charge for this was about 12 to 14 cents per square foot or $1.25 per gallon.

Under the second plan, the termite control operator was able to have the builder include termite control in his job by an appeal to the FHA supervising architect. This work was authorized by the supervising architect under a provision which provided that the FHA architect could require additional precautions that he might deem necessary under local conditions.

### Use of Soil Poisons

The tendency toward concrete slab construction of residences materially hastened the use of preventive treatment against termites. In many areas where concrete slab construction came into general acceptance after World War II, it was widely assumed that such structures would be termite-proof. Experience quickly proved that subterranean termites found openings through and around the concrete slab.

Soil poisoning has been a recognized means of subterranean termite control for years. It is reasonable to assume that a treated soil area beneath and about a building will protect the entire framework of wood of a given building. For years the use of sodium arsenite as a termite preventive material has been well known. However, in areas with subdivisions of residential construction, sodium arsenite has not lent itself too well because of its high phyto-toxicity and its ready dilution with soil waters.

The Bureau of Entomology and Plant Quarantine instituted soil poisoning tests many years ago. This work has been continued by the Forest Service. These tests, together with substantiation by commercial firms including the termite control operators, have led to a substantial list of materials which will perform satisfactorily over a long period of time. Cost of this type of treatment is but a small fraction of the cost of all treated lumber and in addition offers the additional protection of safety to all woodwork of the building. It is true that this preventive treatment to the soil area about a building does not offer protection against decay. However, in many areas of the country, decay is not a sufficient factor to warrant the use of fully treated lumber.

Early in 1954 as the result of numerous complaints lodged with the FHA and the Veterans Administration, it became apparent that existing specifications for new construction did not satisfactorily take into consideration the seriousness of subterranean termite attack in residential construction. A joint study was undertaken by a committee composed of representatives from the Federal Housing Administration, Veterans Administration, Forest Service, and the Wood Destroying Organisms Committee of the National Pest Control Association. As the result of this group working together, a tentative schedule was worked out for those areas where termites were considered to be a major problem. In attempting to arrive at definite specifications for nationwide use, it was found that local conditions varied and that methods generally used in one section did not always give top performance in other sections. Consequently, the FHA engaged the National Research Council to study the problem and make recommendations. The National Research Council assigned this task to their Building Research Advisory Board and the study was undertaken.[2] It is now apparent that even better solutions to the problem can be found, but in order to accomplish this we must encourage closer cooperation between the groups involved. After all, performance is still what counts.

There are limitations to the use of soil poisons for termite control. As a termite control operator, I do not believe that their use is the final answer to all problems.

### Assistance of Termite Control Operator

The termite control operator today is in a good position to act not only as an applicator of materials for such operations but to assist, in an advisory capacity, the architect and engineer in the design. The termite control operator has a first hand opportunity to study the performance not only of materials but of methods of construction as well. He sees the failures and shortcomings of design and because of his competitive position, he is very cost conscious.

The termite control operator today is a man of special training, frequently from some of the top colleges and universities of the country, with a background not only in entomology and chemistry but also training in architecture, forestry, engineering, business, and public relations.

In addition to this specialized training, over 900 firms are joined together in the National Pest Control Association. This association, together with several large universities, has regional short courses each year. Purdue University this year held its 20th conference. Several hundred servicemen and operators attend these regional conferences. These conference programs have subjects suggested by problems from the industry and the staff of the school provides the teachers or speakers from allied industries. Classroom sessions and laboratory work are carried out. Fellowships and graduate study are sponsored by member firms and by the national association.

In 1956, the National Pest Control Association sent out questionnaires to 36 extension entomologists in the 36 states where termites are known to be a problem. It is interesting to note some of the comments that were given by the state entomologists. The information given was quite pertinent in that it directly affects the question of "Can wood be used successfully and economically in home building today." Here are some of the more pertinent needs from their replies.

1. General education of the public on termite control, especially architects and construction engineers.
2. National Pest Control Association should cooperate in making people more conscious of the importance of soil poisoning for subterranean termite control and in letting them know that termite shields are no guarantee that the house will not become infested.
3. Research is justified on methods of protecting slab construction and to determine the residual life of termite soil poisons.
4. Research on methods of termite proofing suitable for our area with emphasis on treatment to prevent infestation in new structures.
5. Research justified on the value of permanent control installations and the value of preconstruction controls.

It definitely is a responsibility of the architect to properly design the

[2] See Forest Products Journal VI(11)485–488.

building. Those materials which are subjected to extreme exposure should have proper treatment to protect it. Those materials in the building which have less risk should also be protected. This requires that certain members should be pressure treated. Certain others should have the application of surface treatments such as the three-minute dip and in general an overall protection of the entire premises by good soil poisoning.

Termite control shields, while an aid to protecting a building, are frequently misapplied, are readily subject to damage and as such are not as effective as they could be. Shields, as they have generally been used, have been applied by local tin shops and others thoroughly unfamiliar with the habits of termites and without regard in most instances to the correct method of application. Too frequently termite shields have been indicated as a termite-proofing operation rather than a termite control aid. Competitive bidding for shield installation among the various tin shops has made it necessary that shields be installed or prepared by unskilled labor with the result that poor quality installations are the rule.

## Conclusions

We have a need for some method which will allow the use of lumber at its lowest price for residential construction.

Pretreatment by termite control operators seems at the present moment to offer this service. An additional service is also provided as a by-product to protecting the building. That is, through the use of soil poisoning, the termite control operator not only protects the woodwork of the building but also the contents of the building. Damage to the contents is frequently more costly than repair of some structural members.

Protection of woodwork in a building, particularly in residences, lends itself well to the going operations of the various termite control operators. At the present time there are few areas of our country where pretreatment termite control by soil poisoning is not available at a reasonable cost. It is available in areas where other methods of protection are too costly. Depending on the competitive picture, it is possible to buy good soil poisoning for termite control at approximately 10 cents per square foot of building area or less. This makes the initial cost on an average small home approximately $100. Such prices are competitively less than treated lumber and compare favorably with the cost of installing good termite shields.

At the present time there are under discussion ways and means of reinforcing or making more valuable the pretreatment service of our industry. Presently, most firms are offering a five-year retreatment warranty which provides that in the event termites should reoccur, the termite control company will retreat without any additional charge. Other firms have gone a step farther than this and in connection with an annual service policy at a modest sum of some $10 to $15 per year, are actually guaranteeing replacement of damage should such occur. In the foreseeable future, replacement guarantees will be made a general policy of all firms doing this work. Reinspection service, which only our industry offers, is a valuable part of building maintenance. Under this service plan we are able to inspect and detect termite infestations, which would go unnoticed for a number of years, as well as take necessary corrective steps in time. This service also provides the property owner with a report of other conditions which may exist about the property such as leaking plumbing, water seepage, gas leaks, and other items which may impair the home investment.

Good planning, sound construction features, ample clearance in floor joist construction, the use of treated lumber for elements of high risk exposure, and proven soil poison application with regular reinspection assures this industry of the continued use of lumber as a construction material.

## Discussion

*John Reno* (Pacific Lumber Co.): Concerning Mr. Smith's comments on the poor protection obtained by improperly built or improperly installed metal termite shields, I think he will agree that equally poor protection will be obtained from a poor job of soil poisoning or a poor job of pressure-treating lumber. He speaks of competition among pest control operators and mentions constantly lower prices—this might indicate lower quality jobs.

If metal termite shields are properly built and properly installed, they make the termites come out into the open where they can easily be seen and just as easily eliminated by tearing down their tunnels, which will be in plain view.

Treated or naturally durable lumber merely protects the treated member itself, such as the sill or joists. The termites easily build their tunnels around the treated lumber and attack the studs, floor, carpets, and even the furniture. As far as decay is concerned, treated lumber is not necessary if we keep moisture away from the wood and this we do in crawl spaces by using soil covers.

As far as soil poisoning is concerned, the home owner should be entitled to a firm guarantee against all damages, including contingent liability, from the soil poisoner who charges for the original job and then a monthly fee for maintenance.

I believe the wide-awake pest control operator should investigate the value of a combination of good soil covers and good metal termite shields to protect against both termites and decay, and consider adding these methods to his services. I believe this combination holds the best promise today.

*Eldon A. Behr* (Chapman Chemical Co.): What is wrong with termite shields? Do they really serve a valuable purpose? Can termites crawl up brick veneer at joints without being seen?

*Mr. Smith:* Basically termite shields will do an excellent job if the system is inspected frequently; however, these inspections are seldom carried out properly. It is true that with brick veneer construction where you have a contraction and expansion of the metal shield in the mortar, breaks will eventually occur and the house is open to termite attack with little chance of their being discovered.

In regard to soil covers, I do not feel they will keep all moisture out as water will sometimes puddle in the wall above the shields furnishing a good supply for termites.

*Mr. Reno:* Where does this water come from?

*Mr. Smith:* Water comes from rain blowing through the walls. I have found water 4 inches deep in some walls—so deep that it overflows out over the interior floors.

*R. B. Putman* (Koppers Co.): What is the persistence of soil poisons over long periods of time?

*Mr. Smith:* We are not too sure but tests have indicated that in exposed areas they have lasted up to 10 years. Treatments made during the 1930's are still good—a good estimate might be 20, 30 years or longer.

*R. J. Kowal* (Southeastern Forest Experiment Station): Regarding the persistence of poison, our tests have shown that sodium arsenite treatments have lasted 12 years so far in the Canal Zone; some of the hydrocarbons have been under exposure for 10 years. Much longer periods of service are expected. One caution, however, no matter how effective, poisons must be properly applied.

*P. B. Mayfield* (Barrett Division, Allied Chemical & Dye Corp.): What chemicals are considered best for use as soil poisons?

*Mr. Smith:* Sodium arsenite, Chlordane, Dieldrin, Lindane, Pentachlorophenol, DDT and others.

*Ralph M. Lindgren* (U. S. Forest Products Laboratory): If retreatments under concrete-slab houses are necessary, have methods been considered to accomplish these treatments?

*Mr. Smith:* Yes, we now have a method whereby during or after construction we can place tubes or pipes under the house permanently to resaturate the area concerned.

*Mr. Kowal:* It is my belief that further research is needed to determine distribution of chemicals in soils when treated by a piping system.

*Tom Forshaw* (Chapman Chemical Co.): Is it not feasible to use a combination of wood preservation and soil poisons in residential construction: one to protect wood from decay and the other to protect it against termites which might move up over treated wood?

*Mr. Smith:* Yes, I believe a combination of the preventive measures should be practical. All segments of those involved must cooperate if houses are to be adequately protected.

*C. Miles Burpee* (American Wood Preservers Institute): I concur in what Mr. Smith says. However, I wish to point out that no amount of soil poisoning will prevent decay.

*Ray Osborne* (American Wood Preservers Institute): What avenues are open to us to eliminate decay and termite damage in slab houses?

*Mr. Smith:* A combination of treatments is the answer: architects should get the houses off the ground, we should use well-treated material when it is in contact with concrete, near the ground, or subject to condensation. Soil poisons and termite shields will not stop condensation and decay. All treatments must be properly employed if they are to give satisfaction.

*Raymond H. Matson* (American Cyanamid Co.): How far north does termite damage extend?

*Mr. Smith:* There have been cases of termite damage north of Chicago, but of course, the number of cases are not as numerous in northern U. S. as in the south. The increased use of air conditioning is extending the northern limits of termite damage.

*Mr. Mayfield:* I recently ran across a serious case of termite damage in Chatham, N. J.

*Ira Hatfield* (Wood Treating Chemicals Co.): The Building Research Advisory Board report to FHA has recently described four areas of intensity in the United States for termite and decay damage and they are recommending specific treating practices for each area. Perhaps A. F. Verrall, a member of the committee, would care to comment on this point.

*A. F. Verrall* (Southern Forest Experiment Station): Termite damage occurs over much of the country but is definitely most severe in southern latitudes. In general, overall decay hazard follows the same pattern but serious decay can occur in any section of the country. The problems, however, are different in the north and south. Decay of exterior woodwork, associated with rain seepage, is most severe in the southeast while that associated with condensation is more troublesome in the north.

# Wood, Research, and Economic Growth in California[1]

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**The potential for further sound growth of the forest industries in California is discussed, with research seen as the key to its realization. The role of the California Forest Products Laboratory in helping meet the state's wood research needs is pointed out. The general scarcity of technically trained men is viewed as a possible bottleneck in meeting the challenge to grow, with the need emphasized for stimulating interest in careers in the forest products industries.**

THE FUNDAMENTAL PROBLEM which seems to embrace virtually everything that is going on in California today is the problem of economic growth. The evidences of growth are all around us in the form of more people, more automobiles, and more smog. The problems of growth provide most of today's news and topics of conversation, whether that topic is the water problem, the education problem, the traffic problem, or some other necessity triggered by the State's remarkable expansion. No great wisdom is needed to note that how well we recognize and solve the problems which growth poses will do much to determine how we fare during the next decade or two.

Forest resources and forest products research are both vitally related to the problems of economic growth, particularly in the northern half of the State where wood resources occupy such a strategic economic position. We are all familiar with the fact that the output of wood products in California today is just about twice what it was immediately after World War II. This expanded output has provided a major share of the physical materials needed to construct new homes to house the 5 million new residents of the State and to provide schools and other essential facilities for them. It has contributed materials to package expanded production of manufactures and components for many of these same manufacturing industries. In total, the value in service of these wood products used in the State is of the order of $1 billion annually.

But the most significant contribution which forest industries have made is probably not measurable in physical and dollar terms. It is apparent that California could not have enjoyed the growth and prosperity characteristic of the last decade without having had ever-expanding opportunities for employment. Without a continually wider employment base, living standards would have had to fall and migration into California would have been seriously discouraged. The expansion of our wood products output has provided one of the primary sources of the new jobs needed to accomplish our recent

[1] Presented at meeting of FPRS Northern California Section, April 27, 1956, in San Francisco, Calif.

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economic development smoothly. The basis for an accurate measure by this yardstick of the importance of forest industries and resources does not exist. But a rough appraisal of what has happened suggests that probably almost a fifth of the 2 million people who have come to northern California since 1945 have been absorbed into the economy either directly or indirectly as a result of the expansion of forest industry activity.

This is a tremendous accomplishment and one that has perhaps been too little recognized. But it automatically raises the question: "Can forest industries continue to be a foundation for economic growth in the future? Can the forest industries create as many new jobs in the next decades as they did in the last one?"

### Current Resources

Part of the answer to these questions may easily be read in the recently completed wood inventory of the State. In 1953 the total old-growth timber supply of all species in California was 305 billion board feet. Annual cut was a little under 6 billion and new growth amounted to 3 billion board feet each year. With old growth inventories 50 times as great as our present annual cut, one might be tempted to believe that considerable further expansion in the level of wood products output is probable. However, a little closer look at the situation will indicate that the reverse is more likely to be true. Half of the total commercial timber volume is on the National Forests where allowable cut, rather than total inventory, is the appropriate measure of timber supply. The allowable cut for the National Forests is currently set at 1,345 million board feet per year. Actual cutting during the present fiscal year is expected to amount to slightly over 1 billion feet. Thus, future production from National Forests is likely to rise by little more than a third of a billion feet as the full allowable cut is reached.

About a fifth of the commercial forest area of the State is owned by forest industries. Increasingly, such lands are coming under Tree Farm management which relates the cut from the forest to long-term wood needs of established industrial plants. It seems likely that the future wood output from these industrial lands will support sawlog production of roughly 1–2/3 billion board feet. In very broad terms, then, public and industrially owned lands seem likely to support output in the future at a level of about 3 billion board feet per year.

The remaining 27 per cent of our forest is held in miscellaneous private ownerships which appear to account for 50 or 60 billion feet of old growth inventory. At the present time, the sketchy available evidence suggests that 2 to 2½ billion feet of present cutting is concentrated on these non-industrial private ownerships. The ratio of current cut to inventory there indicates no room whatsoever for long term expansion of log production. In fact, it seems almost inevitable that total output from such lands will start to decline sharply within about a decade. Thus, it may well be that California has already reached the peak of its sawlog output. And it appears virtually certain that we can expect no such further increase in log production during the next 10 years as we have had in the past decade.

The conclusion one is forced to draw is, therefore, that we have reached the end of a major avenue for economic expansion provided during the past decade by forest resources and forest industries. The challenge to open up new directions for growth is therefore clearer and more pressing than it has ever been before. Because of the nature of their markets, the forest industries will be among the first to feel the ill effects of any check to expanded employment. Recent estimates indicate that 1,650,000 new employment opportunities will be required in the next 10 years to absorb our expanding population. If forest industries cannot provide their share of these new openings through the simple means of bigger production, then it behooves them to look hard and long for alternative ways of doing the job. For merely to ignore the problem of growth would be not only to ignore the industry's responsibilities but also to overlook the fact that unless more jobs are provided and more people employed, existing forest industry markets in the State will suffer drastic shrinkage.

### Avenues of Potential Growth

Fortunately, the wood resources are not limited to sawlog products. Other important avenues of potential growth are available. Inventory figures show 395 million cu. ft. of unused logging and plant residues produced in California in 1952—1 cubic foot for every 14 board feet of logs produced. Full use of such leftovers would raise the physical volume of usable wood products by an amount roughly equal to the expansion of the last decade. Even if we only achieved in California the average level of utilization which prevailed nationwide in 1952, the industrial impact would be roughly equivalent to expansion of the cut by 1½ billion board feet. Such an improved level of utilization would probably absorb 30,000 to 40,000 additional workers in wood manufacturing.

A big unexploited opportunity for industry growth, then, lies in more complete and thorough use of wood raw materials. And the stakes for which we are playing in stressing closer utilization are not only those of the profit of the individual business. The vital stake of maintaining an exexpanding California economy and of the very markets on which existing wood using industries depend are also involved.

To meet this challenge—to enable our forest resources to sustain further substantial increases in the size of the economic pyramid which they support —requires work along three lines. One is the development of new products and techniques using classes of material now considered as residues. A second is the development of lower costs of production through improved methods of manufacture, in the case of products and processes already in use or already known. The third is the development of the expanded market without which technical and cost advances will be abortive.

It needs no argument to show that if we are to make adequate progress along these three lines we need much more effort in all phases of forest products research. Such efforts must include so-called fundamental research to provide a larger backlog of technical facts and information. Equally necessary will be more applied research at pilot plant and operating levels, better application in practice of the results of research already accomplished, and critical attention by highly competent engineers and technologists to the problems of cost and market development.

### Meeting Research Needs

To meet these needs, substantial research programs by private industry, by industry associations and by public agencies have been making important contributions for many years. Now, establishment of the Forest Products Laboratory at the University of California is beginning to throw considerably more manpower and equipment into the research job.

At the Forest Products Laboratory in Richmond we now have two new buildings covering 20,000 square feet and containing over a third of a million dollars worth of research equipment. The Laboratory staff presently consists of a Director, three technical research men in the Division of Forest Products Chemistry, one man in the newly established Division of Timber Physics and Mechanics, and adequate clerical and shop staff to support them. During the next twelve months we hope to add four more full-time research people. Present planning calls for continued steady expansion over

the next four years, by which time the research staff should have grown to its permanent operating level of about 25 full-time technical workers.

The plan for development of the Laboratory's program envisages undertaking major areas of research one by one, as the expanding staff permits, rather than trying to tackle everything at once. Thus work in the Wood Chemistry Section actually began some six years ago and now embraces over 30 projects in this particular field. Work in mechanical and physical properties had to await completion of the research plant. The initial projects in this area have now been started and the work will expand as soon as additional personnel are on the job. During the fiscal year 1956–57, research will also begin on problems in the area of gluing and glued products, on fiber products, and on the chemical processing of wood. A year after that we hope to activate research sections to deal with particle boards and protective coatings.

We envisage the staff I have enumerated as the core of the research organization, employed on a permanent basis and financed by funds from the University budget. Beyond this, the Laboratory program calls for close cooperation with industry through the medium of sponsored research. Industry sponsored projects have been underway for some time in the Wood Chemistry Section. The opportunities for such cooperative work will expand as additional Sections of the research program swing into action.

Research studies, no matter how well they are done, are of little practical value unless the results are effectively transmitted to the man in the field and applied to practical operations. We therefore believe that proper dissemination of research information is a vital part of the Laboratory's function. Through publications aimed at the man on the job, through short courses conducted by Laboratory personnel, and through sponsorship of technical meetings to facilitate the interchange of information, we hope that the Forest Products Laboratory can help materially in getting research results from all sources into the hands of men that can use them.

If the research program at the Laboratory is to contribute effectively in maintaining the position of wood resources as a leader in economic growth, that program must clearly be sensitive to the needs of the forest industries. In recognition of this President Sproul has appointed a Technical Advisory Council for the Forest Products Laboratory comprised of people in the several forest products industries with intimate familiarity with research needs. This twelve man Council, under the chairmanship of Mr. E. B. Birmingham, has held two meetings at the Laboratory within the past six months and has already aided us greatly with valuable suggestions and guidance in planning future work. We feel that the Council will play a very important role as a means for keeping Laboratory programs closely knit to industry needs.

The strong support which the Laboratory is receiving from the University administration, plus the vigorous and constructive actions which industry has taken both to initiate and guide this new research effort promise well for the future of the Forest Products Laboratory. I have already tried to indicate why we feel that the research problems with which the Laboratory will deal are vital ones—to the State as well as to the industry. We also believe that the Laboratory program is a major forward step in meeting these needs for wood research.

But none of us believes that any single laboratory can do all of the varied jobs of a research character that are required if we are to retain the competitive stature of wood using industries and resources in an expanding California. If, during the next decade or two, we are to accomplish the fundamental research, the industrial research applications, and the engineering and marketing development work which are essential for continued growth of forest industry, redoubled efforts are going to be needed both to get more research under way and to insure that the results of research have a maximum effect in the world of industrial practice.

## The Job Ahead

The recent report by Kaufert and Cummings on "Forestry and Related Research in North America" indicates how far our research efforts in the forest products field are lagging behind the general trend of development. All expenditures for wood utilization research in the U. S. currently amount to about one fourth of 1 per cent of the annual value of wood products.[2] In contrast, those industries which have shown the most rapid growth in recent years have been spending 3 to 4 percent of the value of their sales on research and development. The average research expenditure for all U. S. industry is about 1 per cent of product value. Thus, to bring wood research in California up to a par with the average of all U. S. industry would mean research and development outlays of around $5 million per year. Clearly the encouraging recent growth of forest products research in California represents a strong beginning—but still only a beginning—on the job that needs to be done.

If research is to continue to expand and if industrial application of research results is to be effective, we are going to need a considerably increased supply of men well-trained in the forest products field. The general scarcity of technically trained men is widely recognized. Anyone who has tried recently to recruit men is well aware that the shortage is as acute in the forest products field as in any other. It seems apparent to me that technically trained manpower is thus one of the crucial bottlenecks which may limit our success in meeting the challenge to grow.

Providing adequate training in wood products is, of course, one of the jobs for which the School of Forestry has responsibility. We are currently working to broaden the wood utilization program available in the University for graduate students at both the Master's and Ph.D. levels. Similar broadening of wood utilization offerings at the undergraduate level is not far away. However, no course of instruction is better than the students who elect to take it. Today, with salaries for graduate engineers verging on the fantastic and with opportunities in many other fields glamorized by eager personnel managers, it seems to me that we may not be getting into the wood products and forestry fields our fair share of the able high school graduates. The competition for the career interest of these young men is strong. The opportunities in the forest industries are not yet well understood by most high school students faced with a career decision.

Through its Industry-Education Committee the Forest Products Research Society is stimulating interest at the level of the college undergraduate. But there is reason to feel that adequate numbers of young men of top-notch potentialities will not flow into training for and employment in forest industries until the opportunities there are more clearly presented to them before they enter college. Engineering, business administration and many other occupations are participating effectively and on a broad scale in high school "Career Days" and similar programs designed to inform people of career opportunities in these particular professions. Unless forest industries also participate in programs at this level, we will fail to compete effectively for the top-notch student material.

Last winter the Northern California Section of the Society of American Foresters, recognized the importance of this problem. Through its Committee

[2] Kaufert, F. H. and W. H. Cummings. *Forestry and related research in North America.* Washington 1955. p. 161.

on Career Counselling, established for the purpose, that Society is beginning to channel information on forestry career opportunities, educational programs, and related subjects into the hands of high school students. For a number of years the engineering societies have been very active in this kind of work. Perhaps this Society, too, should consider some similar program to assure the forest industries of an increasing number of highly intelligent and well trained young men, competent to handle the increasing need for technical development.

In conclusion, there is no doubt that our wood resources contain tremendous potentials for further sound growth of forest industries in California. The research know-how which is largely concentrated in the members of this Society is the key to realizing those potentials. Your record of past research accomplishments leads one to believe that in the future wood, through research, will continue to contribute to our economic growth.

# Automation in Lumber Milling[1]

STEPHEN M. BATORI

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**Analyzes factors which are important in consideration of automation and describes typical examples of successful applications of automation in a sawmill or planing mill. Advantages are given of mechanizing operations and controlling that mechanization to achieve maximum productivity and utilization with minimum manpower.**

THE USE OF AUTOMATION does not have as its only function, perhaps not even the primary function, the replacement of manpower, but rather the maximum utilization of manpower. It is the electric motor, or the steam engine, that supplies the mechanical power with which man has been able to increase his productivity so many times in the past decades and centuries. It is automation which is going to make it possible for man to control the vast power and energy which has been put at his disposal.

Here are some factors which are just as important, if not more so, in connection with automation, than the consideration that manpower can be eliminated in some particular process.

1. **Maximum Utilization of Manpower:** If a man does not have to do something a machine or control device can do, he is in a better position to carry on the jobs which only he, a thinking person, can do. The machine cannot compete with him in grading, for example.

2. **Accuracy:** Any process which involves such physical measurements as length, width, thickness, color, density, moisture content, roughness, weight, or straightness, or many other characteristics, can be measured with greater accuracy by a mechanism than by a man because of the greater inherent sensitivity of the machine.

3. **Absence of Fatigue or Mental Disturbance:** The automated machine, much more accurate than manpower at eight in the morning when the shift begins, is equally as accurate at five in the afternoon when the shift ends. The same can hardly be said of the man trying to do the same job. Also, the repetition of a boring task is not conducive to best performance by manpower.

4. **Elimination of Mistakes:** The properly designed automatic control will repeat sequences and will recycle in proper order without mistake or error. That can hardly be said of manpower. In the chemical industry, for example, hand batching was always liable to error; automatic batching does not suffer from this defect. The machine that has its operation automatically controlled will go through a complex cycle consistently, so that checking can be practically eliminated or can be made part of the control itself.

5. **Safety:** The automatically controlled machine is much safer than that which is man controlled. However, the automatic cycling of a machine must be capable of having control taken over by manpower in an emergency. The machine cannot think. It can add, multiply, or integrate, but it cannot think.

All of these factors add up to a definite warning that if we wish to maintain good quality control, we must make our processes as automatic as possible and to take away from human beings all those process controls which a machine can do better than the man. If quality control improves, the yield or utilization from raw materials improves and we remain competitive both within our industry and in competition with other materials which may lend themselves more easily to automated processes.

In spite of the many years of progress in the sawmill and planing mill industry, very little has been done to automate processes. What little has been accomplished has been done within the past two or three years. Consideration of the reason for the scarcity of automated processes in the sawmill and planing mill raises some issues which have made the advent of automated processes more difficult in this industry than in many others.

First and foremost of the reasons why we have experienced so little automation is the fact that the raw material with which we work has so little uniformity. Logs vary in size, in shape, in density, and moisture content. Boards, while they are, at least in theory, made to uniform size, do vary in length and in moisture content and density. As we go further along the manufacturing process, ending up at the planer and the grading table, it is increasingly easier to make possible automatic processes and their advantages.

## Applications in Lumber Manufacture

Where can automation be applied successfully in a sawmill or planing mill? Here are some typical examples.

A. For some types of applications, a riderless carriage can do a better job than a carriage that has a rider. There is always the possibility of misinterpretation of signals between the sawyer and the setter on the carriage. The argument has been raised, why not let the sawyer punch a button rather than using his finger for signalling? This argument has some merit, but the practicality of a riderless carriage has not been demonstrated for all types of cutting.

B. Automatic pre-setting set works for re-saws. This is a problem of mechanization, as well as automation. Why should the sawyer have to do hard physical work in changing from one setting to another? Because it is

[1] Presented at meeting of FPRS Pacific Northwest Section, May 7–8, 1956, in Eugene, Ore.

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hard work, it is a temptation to leave settings alone when perhaps maximum yield and utilization could be obtained by changing settings. Certainly a preset type of setworks has much to commend it.

C. Pre-setting, remote control shifters for edgers. Much work has been done in this field, both by equipment manufacturers and by the users of such equipment. A remote controlled presetting edger permits higher rates of production and with greater safety.

D. Stackers and unstackers are good examples of automation applied to the control of mechanization. Such stackers and unstackers, properly controlled, do a much better job than straight manpower could ever do at the same rates of production.

E. Knot boring and plugging machines. These machines make possible the economical boring and plugging of knots so that lumber may be upgraded. Doing the same job manually would be uneconomical.

F. Lumber end and edge gluing machines. The economical edge and end gluing of lumber would not be possible without automation, i.e., the control of mechanization to make possible a continuous process.

These items enumerated are merely examples of what is possible and are those items that are already in existence. There are many that are talked about and are definitely within the realm of possibility if the problem is tackled now.

### Advantages of Automation

Whether a firm automates by arranging existing standard production machines in product lines and linking them with automatic transfer devices or by building special purpose equipment that will accomplish the desired operations, it makes possible the maximum productivity and maximum yield at the same time. It improves quality control and improves safety. To what extent a company can participate in automation depends on circumstances at the particular mill. Automation demands some investment in equipment. The adaptation of equipment with new transfer devices and new properly designed controls makes possible automation at minimum expense.

One final word of caution is necessary. Automatic devices are not the sort of machines or mechanisms or apparatus that a steam engine used to be 20 or 30 years ago. Some of this improvement in productivity and utilization that will be experienced with mechanized and automated production lines requires more maintenance and more skilled maintenance personnel than may have been provided in the past for mechanical equipment. The crescent wrench, the chisel, and the sledge hammer can be thrown out of the tool bag. Maintenance personnel will have to be trained and provided with adequate tools and instruments. The size of the maintenance staff may have to be increased somewhat. That is the penalty you have to pay for the improvement that automation helps you achieve.

Look at what has been accomplished in those industries with which wood products are competing. Look at steel, aluminum, particle boards, plywood, brick; practically everyone of these products has been manufactured by a process that is appreciably more automated than sawmilling and remanufacturing. If the lumber industry wishes to remain competitive with these products, it must mechanize, and what is more important, control that mechanization to permit achieving maximum productivity and utilization with minimum manpower.

# Developments in the Canadian Container Industry[1]

J. M. LIMERICK and L. D. RICHARDSON

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**Recent developments and new applications of corrugated and wirebound wooden boxes are discussed. Research is described in which a kraft mill developed a high-yield pulping process for linerboard. Hardwoods are being used to produce corrugating board superior to anything manufactured previously. A combination of high yield and hardwood utilization gives more complete utilization and sound conservation of the forests.**

### Developments in Component Materials

THE RESULTS of intensive research into complete utilization and overall conservation of the forests is now showing results in the container industry, especially in those companies which are fully integrated and have pulp and paperboard mills as well as container plants. Much research and development work—in pulping process, in the paperboard manufacturing methods, and in container fabrication—has been applied to the project.

Certain mills making kraft linerboard for corrugated containers have devoted considerable effort to obtain higher yield from the wood and are now operating on "high yield pulping." For example, at the Bathurst Power & Paper Company, where the first commercially successful high yield pulping process was carried out, three cords of wood are now producing the same quantity of pulp as four in the former conventional practice.

In recent years much attention has been given to hardwood species. Mills in the container field have studied the pulping of these species by semichemical methods and have produced a corrugating board of much greater rigidity than anything produced from the conventional cooking of softwoods. This high rigidity is of prime importance in the manufacture of corrugated containers. By thus putting the hardwoods to use, a superior corrugating board has been produced and (because of the semichemical process) at the highest possible yield. A saving has, of course, been made in the equivalent softwood formerly used for corrugating board. Hardwood utilization and high yield pulping of softwood have resulted in complete utilization and overall conservation of the forests of the country.

[1] Presented at annual meeting of FPRS Eastern Canadian Section, March 1–2, 1956, in Toronto, Ontario.

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Fig. 1.—This new-type telescope case is used to pack wooden salad bowls. The top is made of brown wood-grain finish printer-tinted board with green printing. It is die-cut so that a portion may be removed to display the contents.

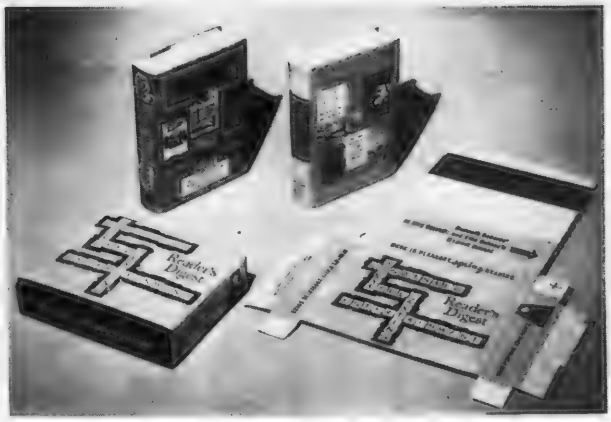

Fig. 2.—Reader's Digest Condensed Book carton started as plain, unprinted kraft and has now advanced to die-cut carton printer-tinted white with two-color regular printing.

### Fundamental Research on Containers

There has been a distinct trend in recent years to examine the corrugated container as a structure from an engineering point of view, and thus convert the paperboards supplied by the mills into the best possible containers. It is perhaps surprising that, until recently, there was really little sound fundamental knowledge as to what important strength qualities should be incorporated into corrugated containers. The effects on these qualities of the various steps in the container manufacturing operations were not fully understood and frequently subject to various personal opinions and prejudices. The only formal strength requirement in the freight regulations was, and still is, the mullen or bursting test. A container measuring up to this test alone could be a good or an extremely poor means of carrying its contents to its destination.

To cope with the situation just mentioned, some companies established research and development facilities devoted to the study of corrugated boxes. Suitable testing equipment has been acquired or specially developed to make a complete evaluation of the container as an engineering structure in relation to its ability to protect and carry its contents. Attention has been given to the special strength requirements of the box for its particular contents. For example, in stacking filled containers, attention has been given to the distinctly different requirements of the box where the contents are cans or bottles, which carry the load, or soap flakes which could not.

As a result of the research investigations and the accumulation of reliable technical data, considerable improvement has been made in the quality of corrugated containers and manufacturing methods. As an outgrowth of the investigations, quality control has been set up as a regular part of the container manufacturing process, and standards of quality are maintained at each stage of fabrication. Records of the authors' company show very clearly that there has been a constant improvement in container quality since the program outlined above was begun. It is felt that further progress is possible as the studies continue.

It might be of interest to mention that about two years ago the Canadian Freight Classification was changed to allow lower weights of linerboards to be used in the construction of corrugated containers. This was in recognition of the fact that progress had been made in the industry, and that proper fabrication of lighter weight liners would produce boxes which would adequately carry the contents. Of interest to the Forest Products Research Society is the fact that the result of the ruling has been to allow the production of more containers from a given supply of wood.

### Specific Examples of New Developments

It might well be concluded from what has gone before that corrugated containers, because of their improved construction and lighter weight, are displacing other more expensive and heavier containers. This is true. Probably the greatest inroads have been made in the field of wooden boxes. The company with which the authors are associated is in the business of manufacturing both corrugated and wooden wirebound boxes. Both will continue to have their place. The corrugated container is now being used in a number of applications formerly using wood, and it is felt that there is no purpose in fighting a prolonged rearguard action against such changes. On the other hand, wirebound boxes are being studied and redesigned and are finding new uses, as will be discussed later.

Some examples of instances where corrugated fibreboard containers are taking over might be mentioned. Nails and bolts are being packed in corrugated boxes in place of the wooden keg. There is the berry crate, the cheese box, and apple box—all made from corrugated board. Baby bassinets and other articles of furniture are now fabricated of the same material.

High wet strength can now be incorporated into paperboard by means of special sizing, and waterproof adhesives are now available for the corrugating operation. This has opened up new fields for corrugated board in providing weatherproof and water-resistant containers for such articles as lettuce, celery, meat, and products which are stored in high humidity.

One rather special replacement of the wooden box is the all-weather retripper. This is a new type of corrugated container for multiple trips within the brewing industry. Its use is expanding rapidly.

Fibreboard is now replacing steel drums in a number of applications. A number of dry chemicals and other bulk products are now packed in fibreboard drums or corrugated containers.

In addition to packages or containers, there are some other relatively new applications for corrugated board. After considerable development work, a corrugated reel is now available for wire, hose, and tubing—taking the place of the heavy wooden reel. There is also the expendable corrugated pallet which is just now receiving acceptance. The pallet, including the posts,

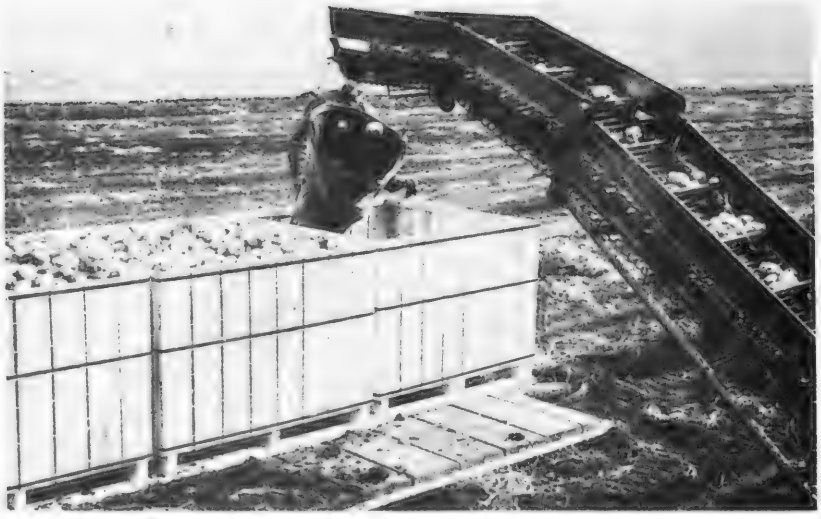

Fig. 3.—Automatic potato picker loading 4- by 4-foot wirebound pallet crates with 1300-lb. capacity. Filled crates can be stacked three tiers high with a fork lift.

is entirely made of corrugated board and is replacing the wooden skid in such applications as the shipping of material packed in paper bags in unit loads.

### Materials Combined with Corrugated Board

For added protection or eye appeal, other films can be laminated to corrugated board. The board can be lined with aluminum foil and thus the container can have insulating properties, or the flat sheets can be used in building insulation. A butter box has recently been introduced in which aluminum foil has been used. Glassine is now being laminated to corrugated board, and the resultant container becomes greaseproof.

Some of the newer plastics are being combined with corrugated fibreboard. In particular, a polyethylene bag within a corrugated box is being successfully used to pack milk, cream, live fish in water, fish in brine, and even corrosive acids.

### Color in Containers

Recently containers have taken on a dramatic new look in colors. The full range of colors is now possible on corrugated boxes. The board can be colored at the mill, or it can be tinted in a separate operation in a solid color or a novel pattern in color. In addition, there is more use of printing and multicolor effects. The striking use of color in corrugated containers is receiving increasing acceptance.

### Wirebound Containers

There are still many uses for certain types of wooden boxes. The wirebound type uses veneer in the major portion of its construction and is bound with wire for added strength. It uses less wood than the nailed box. is shipped flat to the customer, and can be set up very simply and quickly for filling. Very heavy articles are packaged in this type of box, and it also serves as an outside package for a number of smaller boxes whose total might run to several hundred pounds.

A wirebound box need not be totally enclosed, in which case it is a crate, which if properly designed has good structural strength and carries its contents well. It is used in shipments where the packer wishes to be able to examine the article either for damage or other reasons and has the added advantage of using less wood and can be supplied at lower cost. These crates are frequently supplied with built-in pallet for ease of handling by means of a fork lift truck.

Pallet storage bins have received attention in recent years. These are permanent storage bins made of wirebound construction, and having a pallet construction on the bottom so that the bin can be moved from place to place.

The fruit and vegetable markets are still large users of wirebound boxes, especially under conditions where rough handling under adverse weather conditions occurs. Another field is for export shipments where rough handling under all types of weather conditions is common.

Research is being constantly applied to wirebound boxes, and they are being improved in their construction. As a result, they are being used in new applications. In general, wirebounds are being used for much larger articles than formerly, and items such as large motor assemblies are now packed in these boxes.

### Fibreboard Combined with Wood

Where corrugated and wooden boxes are competing, it might be expected that some development in combining the two together would take place. This is exactly what is taking place, and it is the most recent trend in packing larger articles. The best features of wood and corrugated board can be combined to good advantage. A wood framework can give good structural strength and corrugated board can be used for all panels. Variations on this general theme are possible, but the result is a box with good strength and reasonable cost, and it can have added eye appeal because of the ability to print the fibreboard in attractive colors.

Another development, which has received some acceptance in the United States but is just appearing in Canada, is the lamination of paperboard to veneer. Sheets of kraft board are laminated to both sides of veneer. The resultant combined board has the appearance of paperboard and the added strength of the wood, and undoubtedly has some applications. The cost is not yet low enough to receive a wide use, and there are other problems of box fabrication.

### Summary

It can be seen from the above general presentation that a number of developments have taken place in recent years in the container industry. Research and development have produced improved containers, while at the same time requiring less wood per ton of pulp and practicing good utilization and conservation of the forests. New containers are constantly being developed in fibreboard, wood, and a combination of the two.

# Around the World in Forest Products Research and Development

## European Forestry Chiefs Meet in Rome

A review of progress in all fields of forestry in 23 member countries was the feature of a meeting of the European Forestry Commission held May 7–8 at FAO Headquarters, Rome, Italy.

One of the first inter-governmental regional bodies created by FAO, the Commission's purpose is to keep under review Europe's wood requirements and see that national forest policies are designed to fully furnish these needs.

Sir Henry Bereford–Peirse, Deputy Director General of Forestry in the United Kingdom, was chairman of last month's meeting. The group examined the productive potential of Europe's forests over the next 5 to 10 years and timber import prospects from the U. S. S. R. and North America. The Commission then advised courses of action that governments should take in the immediate future for the long term. Proposals were made in regard to future forestry activities of FAO in Europe.

The Commission also discussed technical work carried out by its subsidiary bodies during the past two years and issued directives for further action. Fields covered, for example, were forest working techniques, training forest workers, afforestation and reforestation, flood control and protection from avalanches.

### Simonsen, Noted Turpentine Researcher, Dies in England

Sir John Lyonel Simonsen, known for his researches on forest products, chiefly turpentines, died in England in February. His best known work is his classical treatise, "The Terpenes," first published in two volumes in 1930–32.

Simonsen started his career as research fellow and later lecturer at the University of Manchester. He spent 17 years in India as professor of chemistry and researcher at the Forest Research Institute, Dehra Dun. Returning to England in 1930, he was professor of chemistry at the University of North Wales until 1942.

From 1942 until his retirement in 1952, Simonsen was Director of Colonial Products Research, South Kensington, London. He published about 200 papers during his career, nearly all of which dealt in chemistry of terpenes.

## Scanning World-Wide Forest Products Publications

### Norway

**Investigations of Different Types of Circular Saw Blades for Trimming of Edges of Hard Building Boards.** A. K. Helge. Norsk Skogindustri, Vol. 11, No. 2.

A review is given of the different factors to be considered in the selection of circular saw blades for the trimming of the edges of hard fibre building boards. The selection of blades for optimum quality of cut and long life before resharpening is discussed in regard to shape of the saw teeth, speed of rotation, steel quality, etc. Special consideration is given to saw blades with carbide-tipped teeth. Despite their higher initial cost, carbide-tipped blades were found to be more economical in operation than saw blades made of ordinary carbon tool steel.

Tests were made at a wallboard mill in order to evaluate the performance of different saw blades, by determining their power consumption, as a function of length of cutting time, and by visual examination of the quality of cut. The results showed, however, that over an extended period of testing the variations in the quality of the fibre boards were too wide to allow a reasonably accurate evaluation of the relative merits of the different saw blades in fibre board service.

### Japan

**Studies on the Relation between Moisture Content and Cutting of Wood. I. On the Wood Cutting of the Circular Saw Bench.** D. Hayashi. Journal of the Japan Wood Research Society, Vol 2: no. 2.

Sawing properties of wood resulting from changes in moisture content below fiber saturation point were studied by measuring the time required for sawing in keeping the feed force constant on the circular saw bench. The test material was Katsura.

It was found that cross-cutting is more influenced by moisture content of wood than ripping. When moisture content is over 10 per cent, the sawing property falls down with the value of it. When it is below 10 per cent, the sawing is almost constant. In practical sawing, however, if the moisture content of wood goes below 10 per cent, the saw blade will be tightly gripped between the sawn wood pieces and sawing will become difficult.

## Other Developments Around the World

### Sarawak

• A report to the FAO Asia–Pacific Forestry Commission states that large-scale exploitation of timber is still mainly restricted to Mixed Swamp Forests, partly because they are the most accessible and easily worked, partly because they contain the most valuble timber, 'ramin' *(Gonystylus bancanus)*. These forests are almost invariably worked by hand-sledding the logs to a light railway, by means of which they are in turn transported to a floatable river. In one swamp forest of the 'alan' *(Shorea albida)* type, a sky-line is being used, but the stands of timber in most other types of forest are not large enough to justify such methods. Elephants are used in one Lowland Dipterocarp Forest but have not been a great success.

The number of tree species in Sarawak forests is probably between 2,500 and 3,000, but very few of these can be used at present as timber. Tests of a number of species for use in particle board manufacture are, however, in progress.

—Unasylva, V. II, No. 2

### Germany, Federal Republic

• Following recommendations made at the Twelfth Congress of the International Union of Forest Research Organizations in 1956, an agreement has been reached between the forestry faculties of Freiburg, Göttingen and Munich, the Center for Forest Bibliography, Freiburg, the Union of Forest Research Organizations, Hann. Münden, the Federal Research Institute at Reinbek and the Federal Ministry for Food, Agriculture and Forestry to set up a new documentation center for the sciences of forestry and wood utilization at Reinbek. Its task will be the collection and classification of German and foreign titles, clarification of terminology, and the publication of a journal of abstracts. The center will concentrate at first on European and Asiatic literature and is expected to commence operations soon.

—Unasylva, V. II, No. 2

# Abstracts From Current World Literature

## Machining

**R. Goodchild. The machine boring of wood.** *Forest Products Research Bulletin* No. 35, 1955, 19 pp.

Tests have been carried out on the boring of various species of hardwood and softwood, to relate the performance of the boring bit to the cutting conditions and behaviour of the wood.

Preliminary tests showed that no definite relationship can be established between the torque and thrust required to bore quarter-sawn and flat-sawn material. They are dependent on such factors as the type of bit and its suitability for a particular species, rate of blunting, etc. The torque produced in boring agba was nearly twice as great as that for English lime, probably due to the presence of gum in the former which binds the chips and prevents their removal. The torque and thrust figures for kokrodua (afrormosia) were very high when a Jennings bit was used, but a Scotch Nose bit had a more efficient cutting action and gave a better finish on the bore of the hole.

A study of the work done by the various cutting parts of a Jennings bit showed that more than 50% of the total torque was required by the point and spurs, whereas about ⅔ of the total resistance to feeding was offered by the wings alone. The power required at the spindle appeared to depend largely on the area of wood cut by the wing. Tests to determine the relation of the spindle speed to torque and thrust showed that both factors decreased as the spindle speed was raised, whereas the power required at the spindle increased. [F.D.C. Tech. Bul. V. 6, No. 32]

**S. K. Dean and M. A. Killburn. Simple torquemeter.** *The Engineer,* 11 November 1955, pp. 686–7.

The main feature of this torquemeter is that it can be mounted on a running shaft without absorbing power.

Two discs, slotted peripherally, each mounted on a hub, are attached to the shaft about 5½ in. apart. A light beam from a lamp and lens system has a clear passage through the discs as they rotate under no load conditions, to a photo-electric cell. When a torque is applied the twist in the shaft causes an angular displacement of one disc relative to the other. The slot patterns no longer coincide precisely and a reduced light beam falls on the cell, the reduced reading on the cell microammeter indicating the amount of transmitted torque. (Based on *U. K. Technical Digest* No. 687, published by D.S.I.R.) [F.D.C. Tech. Bul. V. 6, No. 32]

## Resin Identification

**Hummel, Dieter. The identification of plastics, resins and products thereof by their infrared spectra.** Kunststoffe 46, no. 10: 442–50 (Oct., 1956). [In German; French, English, and Spanish summaries]

Infrared spectroscopy can be used for the identification of synthetic resins and lacquers, as well as for the elucidation of the structure of high-molecular substances. Because of the direct relationship between infrared spectra and chemical structure and because of the differentiative capacity of infrared observations, this analytical tool enjoys growing popularity. The theoretical and practical limitations of infrared spectroscopy are discussed, and a systematic scheme for the identification of plastic materials and lacquers is presented. Plastics are grouped in 10 classes—natural products, modified natural products, phenolic resins, polyhydrocarbons, halogenated hydrocarbon polymers, ester resins, ether resins, nitrogen-bearing resins, self-condensation products, and semiorganic and inorganic products. The resolution of mixtures and the application of punched-card system as an aid to product identification are also discussed. [Bul. Pap. Chem. V. 27, No. 4]

## Wallboard Presses

**Roald, Bernt. Transport plates for hard wallboard.** Norsk Skogind. 10, no. 10: 369–70 (Oct., 1956). [In Norwegian; English summary]

The conditions which occasionally lead to a compression of caul plates used in the production of hard wallboard have been discussed previously (cf. B.I.P.C. 25: 456). Based on examinations of discarded caul plates, the earlier investigators recommended that the plates be delivered in a stress-relieved condition with a minimum yield strength of 33 kg./sq. mm. to resist deformation. Recent difficulties of this kind were first ascribed to an increase of the strain in the plates, resulting from reduced closing times of the respective wallboard presses, but examination of discarded plates from presses with different closing times did not verify this assumption. Rather, the extent to which the plates can overcome frictional forces and relieve their internal stresses by expansion during the low-pressure vending cycle appears to be the critical factor. In one press a plate had hardened to a yield strength of 33.9 kg./sq. mm. before further yielding was prevented. It is probable, however, that a plate with the recommended initial yield strength of 33 kg./sq. mm. would have been compressed only slightly under these conditions before further yielding had been stopped. In one plant, operating difficulties resulted from a lateral bending of the caul plates, presumably owing to uneven lengthwise compression caused by uneven temperature distribution within the press. Available results indicate that operational difficulties should not be experienced with caul plates having a minimum yield strength of 33 kg./sq. mm. To prevent even minor contractions, a minimum yield strength of 35 kg./sq. mm. should be specified. [Bul. Pap. Chem. V 27, No. 4]

## Naval Stores

**Pickering, G. B. Oil of turpentine.** Colonial Plant and Animal Products (London) 5, no. 3: 182–200 (1955).

Oil of turpentine is discussed from the standpoint of production, composition, uses, and predictions for the naval stores industry. Four types of turpentine are currently produced: gum, sulfate, wood, and destructively distilled turpentine. The gum turpentine, produced from distilled oleoresin, has long been the most important, but seems likely to be replaced, at least in the United States, by sulfate turpentine, produced from vapors driven off during kraft pulping of pine. Products derived from turpentine include camphor, terpin hydrate, terpinol, terpinyl acetate, toxaphene, terpene resins, pine oil, dipentene, and esters of pinic acid. The outlook for the naval stores industry in general is sound, although diminishing raw materials and competition from synthetics and kraft by-products will keep prices low. World production data, United Kingdom import data, and the various species of pine used in the industry are given. [Bul. Pap. Chem. V. 27, No. 5]

## Particle Board

**Seifert, Karl. Analysis of chipboards.** Holz Roh- u. Werkstoff 14, no. 9: 328–32 (Sept. 1956). [In German]

Of many hydrolyzing and oxidizing agents examined, only 30% hydrogen peroxide solution was found suitable for the preanalytical defiberization of chipboards in such a manner that the urea-formaldehyde resin content was dissolved without unduly high wood losses. On soaking in 30% peroxide solution for 24 hr. at room temperature, only slightly more wood substance dissolved than on 24-hr. immersion in water, and there was no attack upon the paraffinic hydrophobing agents included in the chipboards. Correction factors to be added to experimentally determined wood contents are 2.2% for spruce, 1.6% for beech, and 1.4% for pine chips. The percentage resin content of chipboards can thus be determined indirectly as 100—(W + P + M), where W is the wood content corrected for peroxide losses, M is the moisture content, and P the paraffin content determined by solvent extraction of the separated chips. The resin values thus obtained are reproducible to the same material and to ±0.5% between samples from different boards or board regions. [Bul. Pap. Chem. V. 27, No. 5]

*The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:*

*BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.*

*CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.*

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# Review of FPRS Section Meeting Papers

## Production of Finger-Jointed and Edge-Glued Bondwood

**T. H. Chapman, Great Northern Woods Co., Ltd., North Bay, Ontario. Eastern Canadian Section Meeting, March 1–2, 1956, in Toronto, Ontario.**

Finger jointing and edge gluing is used at Great Northern Woods to upgrade lumber. The operation is predicated principally on production of three grades of 1- by 12-inch shelving, called Bondwood.

With one exception, all machinery used is standard equipment in the woodworking industry. The wood is first blanked by a four-sided matcher, selectively cut for grade by air-operated cutoff saws, the finger joints cut by a pair of end tenoners and then assembled by a specially constructed machine.

Edge gluing is done in a high frequency press and the boards are surfaced on a double surfacer or run through a matcher as required, depending on width. They are then end-trimmed on a moving trim table and sanded by a three-drum sander if the grade specifies it.

Finger joint assembly is accomplished by three specially designed machines fed by a transverse conveyor. Each machine operator removes the relevant grade from the conveyor and feeds it into his machine.

Each of these machines consists basically of a feed table of the endless-belt type, pair of feed rolls, flying cutoff saw, and retractable outfeed table. They have a variable feed speed with a maximum of 60 feet per minute and are designed to assemble boards from 4 to 16 feet in length.

The saw is operated by a movable gate, giving an infinite variation of lengths between these two limits. When the board is cut off, the machine outfeeds on horizontal stringers to the side, making it possible to build up a deck of finished boards.

Originally the standard reversible three-finger joint was used. However, it was impossible to obtain perfect closure consistently, which resulted in open joints appearing on top of the panels. A male and female joint was adopted which consists of two and three fingers respectively of such dimensions that when the finished panel is dressed to ¾-inch thickness, the dressing cuts through the scarf on the outer fingers. This gives a tight joint on the top surface of the boards, even though an opening may appear on the edge where it would not be apparent.

The only restriction on use of this joint is in the direction of feed when the board is being dressed. This must always be in such a way that the cutter knives will not get under the finger and lift it.

Samples of Bondwood have been tested in comparison with white pine by the Forest Products Laboratory in Ottawa. The tests indicate that in the loading ranges where it is most likely to be used (for shelving), its ultimate strength is within 1 per cent of white pine.

## Marketing of Bondwood

**R. W. L. Laidlaw, Laidlaw Co., Toronto, Ontario, and Great Northern Woods Co., Ltd., North Bay, Ontario. Eastern Canadian Section Meeting, March 1–2, 1956, in Toronto, Ontario.**

The major aspects of marketing which are related to Bondwood are product, price, and method of distribution. From a manufacturing standpoint, it was important to consider, among other things, the relationship of plant capacity to the presently available supply of the various combinations that could be produced by finger jointing and edge gluing. Also considered were the position of substitute materials and other lumber species in some of the markets where these possible combinations might move.

The final decision was to aim first for a large number of small customers, with the thought that secondary products and factory rejects might be moved to individual large users. Since large users customarily expect prompt delivery and consistent quality, and since each large user is inclined to have slightly different specifications, we wanted to avoid these markets until all production problems had been solved.

One of the possible combinations of grades and sizes was 1-in by 12-inch, No. 1 and 2 Common white pine shelving. No. 1 shelving was in perennial short supply in Ontario and we could expect ready market acceptance. The initial aim of production, therefore, was to make as much as possible of this grade and size.

Initial production showed the practicability and necessity from a manufacturing point of view of defining a clear grade, since a minor increase in waste percentage enabled production of a substantial proportion of clear material. Production now runs at approximately 1/3 clear, 1/3 intermediate, and 1/3 low grade.

In setting prices, the basic thought was that the lowest grade would have to be sold at cost and the upper grades should make the profit. For the premium grade, the price was set the same as 1- by 12-inch, No. 1 and 2 Common white pine, for which Bondwood was a direct replacement. From a market point of view, Bondwood possessed these advantages: it could be a full 12 inches wide, it was obtainable in specified lengths, it was end-trimmed and kiln-dried.

For clear material, it was decided to set a retail price roughly equivalent to that of ¾-inch fir plywood, bearing in mind the cost of producing wide clear white pine in shop operations.

In view of the plant location, a dual distribution policy was adopted. It was concluded that lumber wholesalers should be able to include Bondwood in carloads of lumber at carload prices, less the usual trade discounts. It was also believed that more aggressive selling would take place if the product was distributed through plywood and wallboard warehouses since the managements of these operations are familiar with the merchandising of new products. The uniform lengths and widths, together with the necessity of wrapping the clear grades, brought the product into a category that the warehouses were accustomed to handling. Distributors were then appointed and wholesale organizations were advised of the availability of the product for inclusion in carload shipments.


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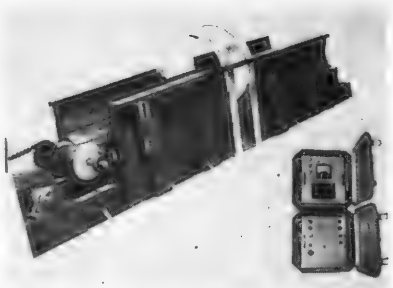
## NEW PRODUCTS—LITERATURE

### Conversion Factor Chart

A reference table of conversion factors for engineers, shop men, and others is available free from Precision Equipment Co., 3716 Milwaukee Ave., Chicago 41, Ill. Published in wall chart form, the table includes such common conversions as inches to centimeters or watts to H.P., as well as many other conversions that are often difficult to locate in reference manuals.

### Metal Detector

A machine which can prevent damage to knives and saws by foreign metal has been developed by the Soderhamn Machine Manufacturing Co., Talladega, Alabama. The device, the Metal-Matic detector, locates foreign metal passing through the log conveyor and causes a horn or bell to



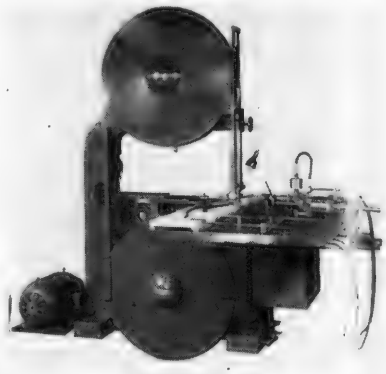
sound and a dye sprayer to mark the general area on the log containing the metal. Also available is an accessory that stops the conveyor.

The unit is completely enclosed, protected from dirt and moisture, and will operate even when partially submerged in the log pond. It operates on an ordinary 110 or 220 volt, three phase circuit, and sensitivity is adjustable.

### Curve Cutting Band Saw

An automatic serpentine curve cutting band saw designed to cut drawer fronts and similar curves automatically from glued up slabs as high as 18 inches has been developed by Tannewitz Works, Grand Rapids, Mich.

A slab is placed on two inner rods just above the table with the forward edge resting on the wooden fixture to the extent of approximately half the

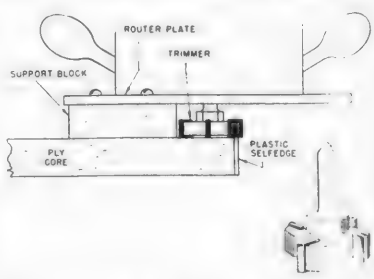


thickness of the cut to be taken. It is locked into position by a hydraulic mechanism, then automatically fed into the saw at a uniform rate. The entire mechanism carrying the slab moves in and out according to the cam setting to produce the curves desired. After the cut the slab is automatically moved back from the sawblade on the return stroke, then the slab moves forward the predetermined distance and the next cut starts.

### Flush Trimmer for Plastics

A four-wing flush trimmer which reportedly increases the speed and accuracy of trimming high pressure plastic laminate self-edging strips has been added to the O.C.E. line of carbide-tipped tools of Price & Rutzebeck, Box 30, Hayward, Calif.

Sized for use in any standard router, the tool eliminates difficult hand-held




trimming on the vertical plane. Plywood irregularities, frequently encountered when riding a narrow trimmer guide on the core, are overcome by use of a quickly-detached wooden support block on the router plate that also gives the operator a solid horizontal guiding platform.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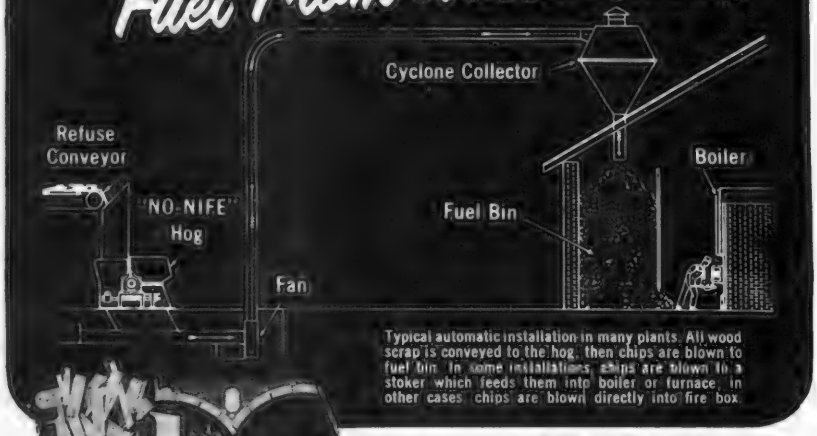
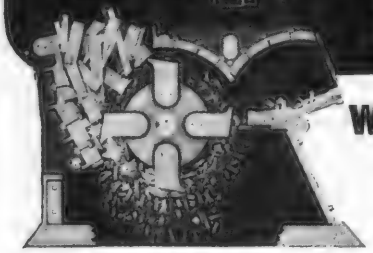



Typical automatic installation in many plants. All wood scrap is conveyed to the hog, then chips are blown to fuel bin. In some installations, chips are blown to a stoker which feeds them into boiler or furnace. In other cases, chips are blown directly into fire box.



Cross section of "No-Nife" Hog showing how fast-moving chisel-edge hammer reduces wood by impact until properly sized to pass through grates in bottom of hog.

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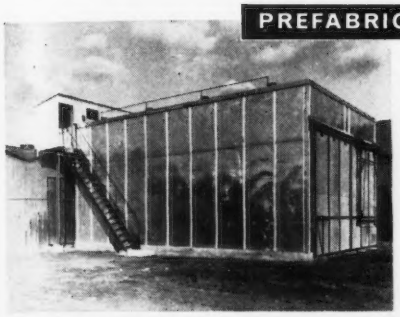

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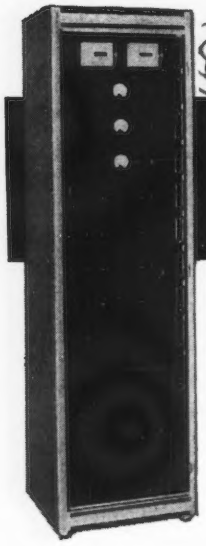

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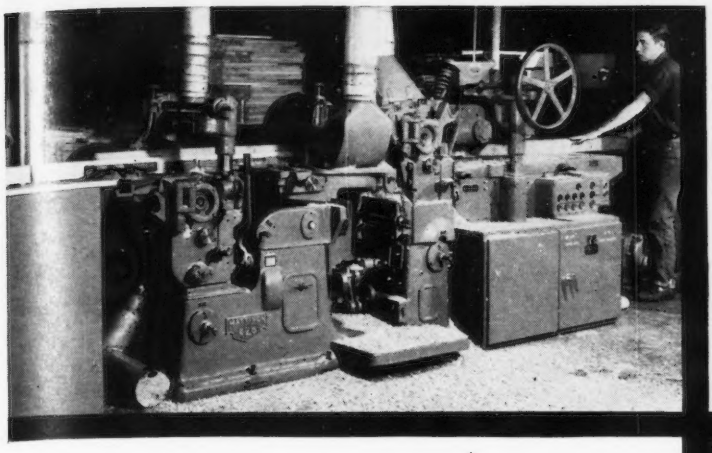
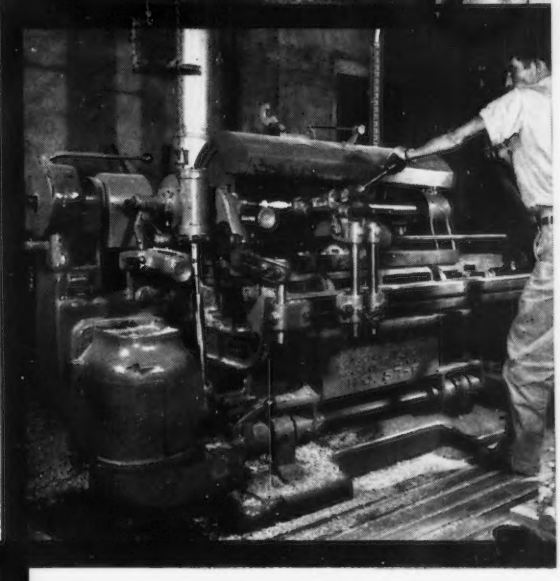


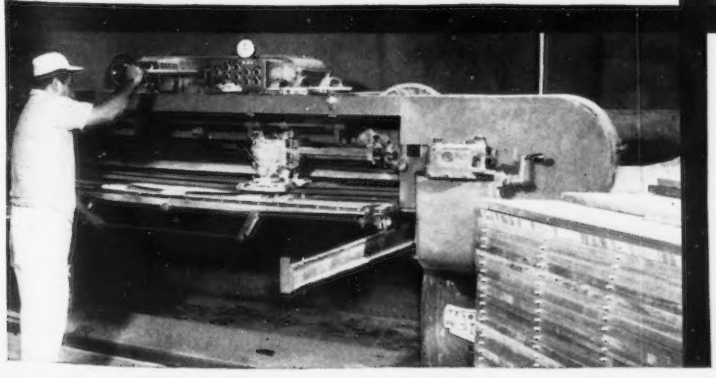
## Rapid Production, High Quality in New Furniture Factory...

# WITH MATTISON PROFIT-PRODUCING WOODWORKING MACHINERY

■ "We're glad we bought Mattison woodworking machines." That's the report from California Furniture Shops, Ltd., after manufacturing colonial and provincial furniture for a year and a half in their new Los Angeles factory.

This company has proved to its satisfaction that rapid adjustments, accuracy, variety of feed speeds, and extra safety of Mattison machines pay off in high-production and top-quality results. They like the way their Mattison 226 Moulder holds adjustments for continued uniformity on long, repetitive runs. Ripping birch lumber on the Mattison 202 Rip Saw produces surfaces of such caliber that joints can be glued without further machining. The ease with which this machine can be adjusted for different thicknesses . . . its repeatedly straight cuts at all feed speeds . . . and simplicity of blade changing are additional factors controlling quality and costs. All shapes, including oval and round table tops, are finished on the Mattison 303 Automatic Belt Sander. This company reports that the sander "does excellent work and reduces the human element of error." Other Mattison equipment in this new West Coast factory includes a No. 231 Knife Grinder, which helps to minimize nonproductive moulder time . . . a No. 57-F Automatic Lathe for turning posts and legs in production quantities . . . and a No. 157 Double-Belt Hand-Lever Stroke Sander. You can get more information on these profit-producing woodworking machines from your Mattison Dealer.





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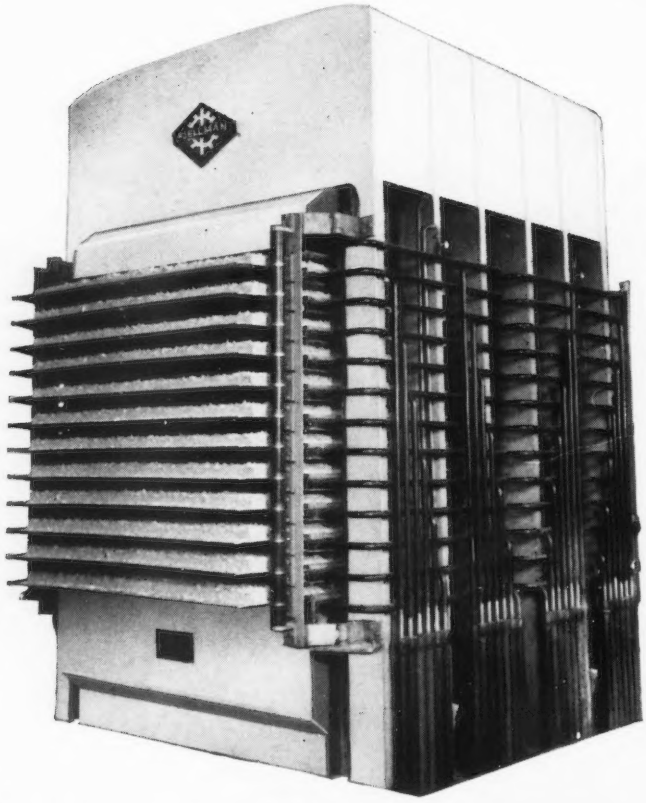
**MATTISON**

**WOODWORKING MACHINERY**

*"Built better...to produce better quality"*

# from Particles to Profits

## FJELLMAN AMERICAN HYDRAULIC HOT PRESSES



More than ten years research and experience with particle-type board presses—and a close association with top manufacturers here and abroad—has resulted in a Fjellman American hot press capable of producing the finest particle-type board by wet or dry processes, either chip, flake, shaving or fibre.

As with all Fjellman American presses, here's a press built to the highest standard of strength and accuracy for long service and minimum maintenance. Each is precision-engineered from fine Swedish virgin steel. Each has box-type frame, light floor-loading properties, American instruments, wiring and hardware.

Available in a wide range of sizes to accommodate the factory interested in capitalizing on its present wood-waste or the largest manufacturer of wood-composition board.

**WRITE FOR CATALOG No. 100-A covering our complete line of industrial hydraulic presses.**

Ask your consulting engineer about our presses or write us for complete information on presses readily adapted to your specific particle-type board manufacture.

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